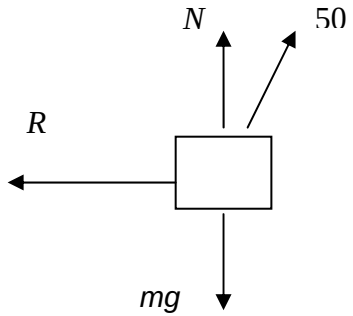
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **1** | *(A)* | | False<br><br>This is a speed-time graph not one for displacement-time | M1<br><br>A1 | **Notice** that the runner may have returned to his starting place or may not; the graph does not contain the information to tell you which is the case.<br><br>**Accept** statements only if they are true and relevant, e.g.:<br>There is no information about direction of travel<br>There is no evidence to suggest he has turned round<br>Distance is given by the area under the graph but this is not the same as displacement<br>Speed is not a vector and so the area under the graph says nothing about the direction travelled<br>It just (or only) shows speed-time<br><br>**Do not accept** statements that are, or may be, untrue: eg<br>The particle moves only in the positive direction<br><br>**Do not accept** statements that are true but irrelevant: eg<br>The distance travelled is the area under the graph<br><br>**Condone**<br>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<br><br>The area under the graph is 420 not 400<br><br>**[6]** | M1<br><br>A1 | Accept area up to time 55 s is 400 m<br>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.<br>Allow, instead, "acceleration is zero", "the particle has constant velocity" and other equivalent statements.<br>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 $a$. |
| | | | $a = 2$ $(\text{ms}^{-2})$ | 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 $t$<br>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]** | |

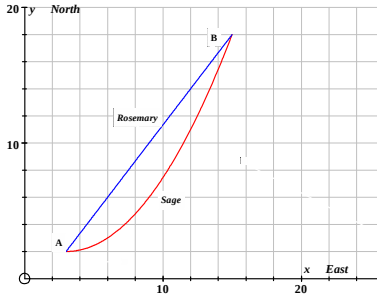
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **5** | (i) | |  | B2<br><br>**[2]** | Subtract one mark for each error, omission or addition down to a minimum of zero. Each force must have a label and an arrow.<br>Accept *T* for 50 N.<br>Units not required.<br>If a candidate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

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 6 | (i) | | **Either** | | |
| | | | Both components of initial speed<br>Horiz $31\cos 20°$ (29.1) Vert $31\sin 20°$ (10.6) | B1 | No credit if sin-cos interchanged<br>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**<br>The ground is horizontal<br>The ball is initially on the ground<br>Air resistance is negligible<br>Horizontal acceleration is zero<br>The ball does not swerve<br>There is no wind<br>The particle model is being used<br>The value of $g$ is 9.8<br>**Do not accept**<br>$g$ 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 $40 \times 0.11$ 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 $760 \times 0.11$ 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,<br>Force down the slope = Resistance force<br><br>$800\ 000 \times 9.8 \times \sin\beta = 33\ 000$<br>$\beta = 0.24°$ | M1<br><br>A1<br>A1<br>**[3]** | Equilibrium of whole train required<br>The evidence for this mark may be obtained from a correct force diagram<br>Allow missing $g$ for this mark only |
| **8** | (i) | | A: $t = 0$, $\mathbf{r} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$, B: $t = 2$, $\mathbf{r} = \begin{pmatrix} 15 \\ 18 \end{pmatrix}$<br><br>$\begin{pmatrix} 15 \\ 18 \end{pmatrix} - \begin{pmatrix} 3 \\ 2 \end{pmatrix} = \begin{pmatrix} 12 \\ 16 \end{pmatrix}$<br><br>$\sqrt{12^2 + 16^2} = 20$ The distance AB is 20 km. | B1<br><br>B1<br><br>B1<br>**[3]** | Award this mark automatically if the displacement is correct<br><br>Finding the displacement. Follow through from position vectors for A and B<br><br>Cao |
| **8** | (ii) | | $\mathbf{v} = \dfrac{\mathrm{d}\mathbf{r}}{\mathrm{d}t} = \begin{pmatrix} 6 \\ 8 \end{pmatrix}$ which is constant | B1<br><br>**[1]** | Any valid argument. Accept $\begin{pmatrix} 6 \\ 8 \end{pmatrix}$ with no comment.<br>Do not accept $a = 0$ without explanation. |
| **8** | (iii) | |  | B1<br><br>B1<br><br>B1<br><br>**[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.<br><br>For the *Sage*, a curve between A and B. B0 for two line segments. Nothing extra. No FT from part (i).<br>Passes through (9, 6)<br><br>Condone no labels |