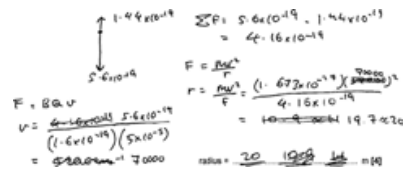


# Mark scheme

| Question |   |   | Answer/Indicative content                                                                                                                         | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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| 1        | a |   | $F (= EQ) = 0.90 \times 1.60 \times 10^{-19} = 1.4(4) \times 10^{-19} \text{ (N)}$                                                                | B1    | <p>Working and answer must both be shown<br/>           Answer must be given to 2sf or more<br/>           Unit need not be given but, if given, must be correct</p> <p><b><u>Examiner's Comments</u></b></p> <p>This was an easy introduction to the question, which used the definition of electric field strength; <math>E = F_E / Q</math>. Being a 'show that' question, candidates needed to show their working in full, including writing the value for the electronic charge (rather than simply 'e') and giving the answer to at least 2 s.f.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|          | b | i | <p><math>(F = BQv \text{ but } B \text{ and } Q \text{ are constant, so})</math></p> <p>(the magnitude of) the velocity is different /changes</p> | B1    | <p><b>Allow</b> speed<br/> <b>Ignore</b> the direction is different</p> <p><b><u>Examiner's Comments</u></b></p> <p>The force on a charged particle moving at right angles to a magnetic field is given by the formula <math>F_{mag} = BQv</math>. Since <math>B</math> and <math>Q</math> are constants in this case, the reason for the different magnitude of <math>F</math> must be that the proton has a different velocity, <math>v</math>.</p> <p><b>Common problems in 6(b)(i)</b></p> <ul style="list-style-type: none"> <li>using the formula <math>F = BI/\sin\theta</math> and suggesting that the proton might be travelling at a different angle to the field, not realising that the proton is always travelling at right angles to the magnetic field in this question</li> <li>suggesting that the proton may be in a weaker (or stronger) field at X than at Y, not realising that the magnetic field is uniform and so its field strength is constant throughout</li> </ul> |

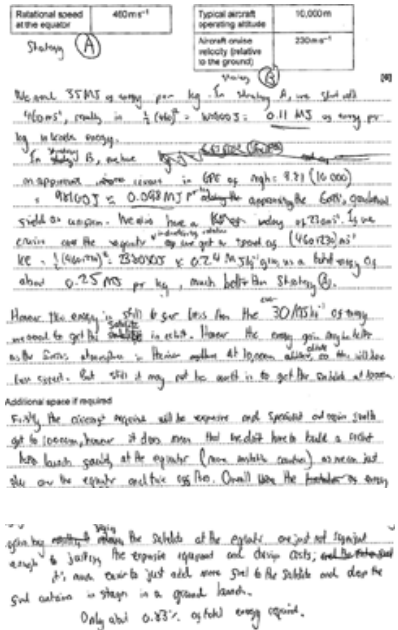
|  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
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|  |  |  | <p> <math display="block">v = \left( \frac{F_{mag}}{BQ} \right) = \frac{5.6 \times 10^{-19}}{5.0 \times 10^{-5} \times 1.60 \times 10^{-19}}</math> </p> <p>resultant force <math>F_R = (5.6 - 1.4) \times 10^{-19}</math></p> <p> <math display="block">r = \left( \frac{mv^2}{F_R} \right) = \frac{1.673 \times 10^{-27} \times (7.0 \times 10^4)^2}{4.2 \times 10^{-19}}</math> </p> <p><math>r = 20</math> (m)</p> <p>ii Alternative all-in-one method:</p> <p> <math display="block">r = \frac{mF_{mag}^2}{F_R B^2 Q^2}</math> </p> <p>resultant force <math>F_R = (5.6 - 1.4) \times 10^{-19}</math></p> <p> <math display="block">r = \frac{1.673 \times 10^{-27} \times (5.6 \times 10^{-19})^2}{4.2 \times 10^{-19} \times (5.0 \times 10^{-5})^2 \times (1.60 \times 10^{-19})^2}</math> </p> <p><math>r = 20</math> (m)</p> | <p><math>v = 7.0 \times 10^4</math> (m s<sup>-1</sup>) implies first C1</p> <p><b>Allow</b> <math>10^{-19}</math> for <math>1.4 \times 10^{-19}</math> (giving <math>F_R = 4.6 \times 10^{-19}</math>) <math>F_R = 4.2 \times 10^{-19}</math> implies second C1</p> <p>Do not credit if used as <math>F_{mag}</math> in <math>F_{mag} = BQv</math></p> <p>Third C1 is for correct substitution into formula</p> <p><b>Allow</b> <math>m_p = 1.67 \times 10^{-27}</math> kg given to 3 s.f.</p> <p><b>Not</b> <math>m_p = 1.661 \times 10^{-27}</math> kg or <math>m_p = 1.675 \times 10^{-27}</math> kg</p> <p><b>Allow ECF</b> for incorrect <math>v</math></p> <p>Use of <math>F_R = 5.6 \times 10^{-19}</math> or <math>= 1.4 \times 10^{-19}</math> is <b>XP</b></p> <p><b>Allow</b> <math>r = 19</math> (m)</p> <p><math>F_R = 4.2 \times 10^{-19}</math> (<math>4.16 \times 10^{-19}</math> to 3sf) implies second C1</p> <p>An incorrect value of <math>F_R</math> is <b>XP</b> from this point</p> <p>C1<br/>C1<br/>C1<br/>A1<br/>(C1)<br/>(C1)<br/>(C1)<br/>(A1)</p> <p>Third C1 is for correct substitution into formula</p> <p><b>Allow</b> <math>r = 19</math> (m)</p> <p><b><u>Examiner's Comments</u></b></p> <p>This question could not be done in one step, by equating the magnetic force to the centripetal force. This is because, at X, the centripetal force is being provided by a combination of forces from both the electric and the magnetic field.</p> <p>The easiest approach is to find the velocity of the proton using <math>F_{mag} = BQv</math> (the value for <math>F_{mag}</math> is given in the diagram as <math>5.6 \times 10^{-19}</math> N). This velocity <math>v</math> can then be used in the formula <math>F = mv^2/r</math> in order to calculate the radius, <math>r</math>. <math>F</math> here is the <i>resultant</i> force towards the centre of the circle, which is found from magnetic force downwards - electric force upwards (the electric force having been calculated in part (a)).</p> <p>Exemplar 3 is an example of a correct</p> |
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|  |  |     |                                                                                                                                                                      | <p>answer, clearly written to show each stage in the calculation:</p> <p>Exemplar 3</p>  <p> <math>F = Eqv</math><br/> <math>v = \frac{4\pi \times 10^{-19}}{(1.6 \times 10^{-19})(5 \times 10^{-3})}</math><br/> <math>= 5000 \text{ m s}^{-1}</math> </p> <p> <math>F = 5.6 \times 10^{-19}</math><br/> <math>F = \frac{mv^2}{r}</math><br/> <math>r = \frac{mv^2}{F} = \frac{(1.67 \times 10^{-27})(5000)^2}{5.6 \times 10^{-19}}</math><br/> <math>\text{radius} = 7.0 \times 10^{-14} \text{ m}</math> </p>                                                                                                                                                                                                     |
|  |  | iii | <p> <math> \text{resultant force}  = (\sqrt{3.9^2 + 1.4^2}) \times 10^{-19}</math><br/> <math> \text{resultant force}  = 4.1 \times 10^{-19} \text{ (N)}</math> </p> | <p>C1<br/>A1</p> <p><b>Ignore</b> attempt to calculate weight of proton<br/> <b>Allow</b> <math>F_E = 10^{-19}</math></p> <p><b>Allow</b> <math> F  = 4.0 \times 10^{-19} \text{ (N)}</math> using <math>F_E = 1.0 \times 10^{-19}</math><br/> <b>Allow</b> <math> F  = 4.2 \times 10^{-19} \text{ (N)}</math> using <math>F_E = 1.44 \times 10^{-19}</math></p> <p><b>Examiner's Comments</b></p> <p>There are two forces acting on the proton at Y: an electric force upwards (given in (a)) and a magnetic force to the left (shown on the diagram). These two forces act at right angles to each other, and so the magnitude of their resultant can be found using Pythagoras's Theorem.</p> <p>Credit was given for using a value for the electric force to 1, 2 or more significant figures.</p> |
|  |  | iv  | <p><u>resultant / net</u> force is not perpendicular to velocity</p> <p>work is done on proton (therefore kinetic energy changes so speed is not constant)</p>       | <p>B1<br/>B1</p> <p><b>Allow</b> direction of motion / path but <b>not</b> speed for velocity<br/> <b>Allow</b> acceleration / <u>resultant</u> force is not (always) towards centre (of circle)<br/> <b>Allow</b> electric force is not perpendicular to velocity / is in the same direction as velocity<br/> <b>Ignore</b> references to centripetal</p> <p><b>Ignore</b> references to centripetal</p> <p><b>Examiner's Comments</b></p> <p>At Y, the proton is moving downwards, with a resultant force being the combination of an electric force upwards and a magnetic force to the left (calculated in part 1). The resultant force cannot be at right angles to the</p>                                                                                                                       |

|   |   |    |                                                                                                                                             |                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
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|   |   |    |                                                                                                                                             |                  | <p>velocity, so we cannot have circular motion.</p> <p>The component of the resultant force acting in the direction of the proton's motion will do work on the proton and change its speed. So, the proton cannot be travelling at a constant speed.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|   |   |    | <b>Total</b>                                                                                                                                | <b>10</b>        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2 | a | i  | $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $\frac{1}{2}mv^2 = \frac{1}{2}\frac{GMm}{r}$                                                             | <p>M1<br/>A1</p> | <p>Allow omission of 'm' on both sides of equation (gravitational field strength = centripetal acceleration)</p> <p>Cancelling/rearrangement/identification of GMm/r as GPE</p> <p><b><u>Examiner's Comments</u></b></p> <p>Many candidates made a good start by equating the formula for gravitational force with the expression for centripetal motion. Others that assumed that g of 9.81 m s<sup>-2</sup> did not score any marks.</p> <p>The simplest way to arrive at the correct expression was to identify GM/r in the gravitational force formula, to rearrange and then multiply both sides by ½. Approximately ½ of all candidates that responded got as far as this gaining both marks.</p> |
|   |   | ii | <p>(Increase in) GPE = (-56 - -63 MJ =) 7(MJ) or<br/>(Increase in) KE = 0.5 × 56 = 28 (MJ)</p> <p>Sensible reasoning, e.g. 7+28 &gt; 30</p> | <p>M1<br/>A1</p> | <p>Allow <b>evaluation of total energy</b> of 35 (MJ)</p> <p><b><u>Examiner's Comments</u></b></p> <p>Many candidates correctly determined how much GPE the satellite needed to gain i.e. 7 MJ in order to reach orbit from -63 MJ to -56 MJ.</p> <p>To find the KE when in orbit, candidates needed to use the result from the previous part of the question. This explains why the in orbit, the KE required is ½ of 56 MJ i.e. 28 MJ. A small fraction of candidates successfully accomplished this step.</p>                                                                                                                                                                                        |

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|  |   |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        | This means the total energy gain is the sum of 28 MJ and 7 MJ i.e. 35 MJ.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|  | b |  | <p><b>Level 3 (5–6 marks)</b><br/>Correct calculations, and advantages and limitations discussed.<br/><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p><b>Level 2 (3–4 marks)</b><br/>Correct calculations and an advantages discussed<br/>or<br/>Correct calculations and a limitation discussed.<br/><i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i></p> <p><b>Level 1 (1–2 marks)</b><br/>Attempted calculations or a single correct calculation or incomplete explanations of advantages and/or limitations.<br/><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 mark</b><br/><i>No response or no response worthy of credit.</i></p> | B1 × 6 | <p>Use level of response annotations in RM Assessor<br/>Ignore general knowledge answers e.g. accidents, cost, politics</p> <p>Allow references to energy, energy per unit mass or potential as interchangeable</p> <p>Allow ecf from candidate's value for total energy per unit mass in orbit from (i.e. 35 MJ) 22bii or use of 30 (MJ)</p> <p><b>Indicative scientific points may include:</b></p> <p><b>Calculations</b></p> <ul style="list-style-type: none"> <li>• (Minimum) additional KE from aircraft=26 kJ</li> <li>• Additional GPE from aircraft = 100 kJ</li> <li>• Additional KE from equatorial launch=110 kJ</li> <li>• GPE calculated by mgh as an acceptable approximation</li> <li>• (Without taking Earth's rotation into account,)KE at equator is about 4x aircraft KE</li> <li>• GPE calculated from <math>vg = (-)GM/r</math></li> <li>• Total energy = <math>0.5GM/r</math></li> </ul> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>• Aircraft launch provides KE and GPE</li> <li>• Aircraft velocity will be higher than 230 depending on where the aircraft takes off.</li> <li>• Less (rocket) fuel required</li> <li>• Aircraft launch has similar/slightly larger energy to equatorial</li> <li>• Equatorial launches can only happen in limited locations/aircraft launches can take place almost anywhere</li> </ul> <p><b>Limitations</b></p> |

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|  |  |  |  | <ul style="list-style-type: none"> <li>• Aircraft launches only suitable for small satellites.</li> <li>• Effects (for either) only significant for near earth orbits/low altitudes</li> <li>• Either launch provides very small fraction (less than 1%) of the energy required</li> </ul> <p><b><u>Examiner's Comments</u></b></p> <p>Many candidates found this difficult to access. A solely qualitative evaluation was limited to level 1 (2 marks).</p> <p><b>Exemplar 2</b></p> <p><i>The initial kinetic energy + GPE will give the total energy gained by the satellite.<br/>On earth <math>\frac{1}{2} \times 1 \times 400^2 = 0.1058 \text{ MJ}</math> of kinetic energy.<br/>On the aircraft, <math>\frac{1}{2} \times 1 \times 230^2 = 0.02645 \text{ MJ}</math>.<br/>However, on the aircraft, the GPE will be higher, and the satellite will need to gain less GPE.<br/><math>\frac{6.07 \times 10^6 \times 6 \times 10^{-3}}{6.37 \times 10^6} = \text{GPE advantage.}</math><br/><math>\frac{6.07 \times 10^6}{6.37 \times 10^6} \approx 0.95</math><br/>In conclusion, although the aircraft would slightly reduce energy required for GPE increase, it would reduce initial kinetic energy by a factor of 4, and there would also be energy required to power the aircraft.</i></p> <p>In Exemplar 2, the candidate has completed a small number of calculations comparing the KE the two methods would raise. There is also a statement that these differ by a factor of 4 along with an attempt at calculating the GPE advantage by launching from the aircraft rather than from the ground.</p> <p>Crucially, there is very little mention of limitation and no supporting calculations.</p> <p>Holistically speaking, therefore, there was not enough evidence to award this candidate Level 3, yet sufficient for a Level 2.</p> <p><b>Exemplar 3</b></p> |
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|   |   |   |                                                                                                                                                |                     |  <p>Rotational speed at the equator: <math>400 \text{ m s}^{-1}</math></p> <p>Typical aircraft operating altitude: <math>10,000 \text{ m}</math></p> <p>Aircraft cruise velocity (relative to the ground): <math>230 \text{ m s}^{-1}</math></p> <p>Station A</p> <p>Station B</p> <p>Station C</p> <p>Station D</p> <p>Station E</p> <p>Station F</p> <p>Station G</p> <p>Station H</p> <p>Station I</p> <p>Station J</p> <p>Station K</p> <p>Station L</p> <p>Station M</p> <p>Station N</p> <p>Station O</p> <p>Station P</p> <p>Station Q</p> <p>Station R</p> <p>Station S</p> <p>Station T</p> <p>Station U</p> <p>Station V</p> <p>Station W</p> <p>Station X</p> <p>Station Y</p> <p>Station Z</p> <p>Station AA</p> <p>Station AB</p> <p>Station AC</p> <p>Station AD</p> <p>Station AE</p> <p>Station AF</p> <p>Station AG</p> <p>Station AH</p> <p>Station AI</p> <p>Station AJ</p> <p>Station AK</p> <p>Station AL</p> <p>Station AM</p> <p>Station AN</p> <p>Station AO</p> <p>Station AP</p> <p>Station AQ</p> <p>Station AR</p> <p>Station AS</p> <p>Station AT</p> <p>Station AU</p> <p>Station AV</p> <p>Station AW</p> <p>Station AX</p> <p>Station AY</p> <p>Station AZ</p> <p>Station BA</p> <p>Station BB</p> <p>Station BC</p> <p>Station BD</p> <p>Station BE</p> <p>Station BF</p> <p>Station BG</p> <p>Station BH</p> <p>Station BI</p> <p>Station BJ</p> <p>Station BK</p> <p>Station BL</p> <p>Station BM</p> <p>Station BN</p> <p>Station BO</p> <p>Station BP</p> <p>Station BQ</p> <p>Station BR</p> <p>Station BS</p> <p>Station BT</p> <p>Station BU</p> <p>Station BV</p> <p>Station BW</p> <p>Station BX</p> <p>Station BY</p> <p>Station BZ</p> <p>Station CA</p> <p>Station CB</p> <p>Station CC</p> <p>Station CD</p> <p>Station CE</p> <p>Station CF</p> <p>Station CG</p> <p>Station CH</p> <p>Station CI</p> <p>Station CJ</p> <p>Station CK</p> <p>Station CL</p> <p>Station CM</p> <p>Station CN</p> <p>Station CO</p> <p>Station CP</p> <p>Station CQ</p> <p>Station CR</p> <p>Station CS</p> <p>Station CT</p> <p>Station CU</p> <p>Station CV</p> <p>Station CW</p> <p>Station CX</p> <p>Station CY</p> <p>Station CZ</p> <p>Station DA</p> <p>Station DB</p> <p>Station DC</p> <p>Station DD</p> <p>Station DE</p> <p>Station DF</p> <p>Station DG</p> <p>Station DH</p> <p>Station DI</p> <p>Station DJ</p> <p>Station DK</p> <p>Station DL</p> <p>Station DM</p> <p>Station DN</p> <p>Station DO</p> <p>Station DP</p> <p>Station DQ</p> <p>Station DR</p> <p>Station DS</p> <p>Station DT</p> <p>Station DU</p> <p>Station DV</p> <p>Station DW</p> <p>Station DX</p> <p>Station DY</p> <p>Station DZ</p> <p>Station EA</p> <p>Station EB</p> <p>Station EC</p> <p>Station ED</p> <p>Station EE</p> <p>Station EF</p> <p>Station EG</p> <p>Station EH</p> <p>Station EI</p> <p>Station EJ</p> <p>Station EK</p> <p>Station EL</p> <p>Station EM</p> <p>Station EN</p> <p>Station EO</p> <p>Station EP</p> <p>Station EQ</p> <p>Station ER</p> <p>Station ES</p> <p>Station ET</p> <p>Station EU</p> <p>Station EV</p> <p>Station EW</p> <p>Station EX</p> <p>Station EY</p> <p>Station EZ</p> <p>Station FA</p> <p>Station FB</p> <p>Station FC</p> <p>Station FD</p> <p>Station FE</p> <p>Station FF</p> <p>Station FG</p> <p>Station FH</p> <p>Station FI</p> <p>Station FJ</p> <p>Station FK</p> <p>Station FL</p> <p>Station FM</p> <p>Station FN</p> <p>Station FO</p> <p>Station FP</p> <p>Station FQ</p> <p>Station FR</p> <p>Station FS</p> <p>Station FT</p> <p>Station FU</p> <p>Station FV</p> <p>Station FW</p> <p>Station FX</p> <p>Station FY</p> <p>Station FZ</p> <p>Station GA</p> <p>Station GB</p> <p>Station GC</p> <p>Station GD</p> <p>Station GE</p> <p>Station GF</p> <p>Station GG</p> <p>Station GH</p> <p>Station GI</p> <p>Station GJ</p> <p>Station GK</p> <p>Station GL</p> <p>Station GM</p> <p>Station GN</p> <p>Station GO</p> <p>Station GP</p> <p>Station GQ</p> <p>Station GR</p> <p>Station GS</p> <p>Station GT</p> <p>Station GU</p> <p>Station GV</p> <p>Station GW</p> <p>Station GX</p> <p>Station GY</p> <p>Station GZ</p> <p>Station HA</p> <p>Station HB</p> <p>Station HC</p> <p>Station HD</p> <p>Station HE</p> <p>Station HF</p> <p>Station HG</p> <p>Station HH</p> <p>Station HI</p> <p>Station HJ</p> <p>Station HK</p> <p>Station HL</p> <p>Station HM</p> <p>Station HN</p> <p>Station HO</p> <p>Station HP</p> <p>Station HQ</p> <p>Station HR</p> <p>Station HS</p> <p>Station HT</p> <p>Station HU</p> <p>Station HV</p> <p>Station HW</p> <p>Station HX</p> <p>Station HY</p> <p>Station HZ</p> <p>Station IA</p> <p>Station IB</p> <p>Station IC</p> <p>Station ID</p> <p>Station IE</p> <p>Station IF</p> <p>Station IG</p> <p>Station IH</p> <p>Station II</p> <p>Station IJ</p> <p>Station IK</p> <p>Station IL</p> <p>Station IM</p> <p>Station IN</p> <p>Station IO</p> <p>Station IP</p> <p>Station IQ</p> <p>Station IR</p> <p>Station IS</p> <p>Station IT</p> <p>Station IU</p> <p>Station IV</p> <p>Station IW</p> <p>Station IX</p> <p>Station IY</p> <p>Station IZ</p> <p>Station JA</p> <p>Station JB</p> <p>Station JC</p> <p>Station JD</p> <p>Station JE</p> <p>Station JF</p> <p>Station JG</p> <p>Station JH</p> <p>Station JI</p> <p>Station JJ</p> <p>Station JK</p> <p>Station JL</p> <p>Station JM</p> <p>Station JN</p> <p>Station JO</p> <p>Station JP</p> <p>Station JQ</p> <p>Station JR</p> <p>Station JS</p> <p>Station JT</p> <p>Station JU</p> <p>Station JV</p> <p>Station JW</p> <p>Station JX</p> <p>Station JY</p> <p>Station JZ</p> <p>Station KA</p> <p>Station KB</p> <p>Station KC</p> <p>Station KD</p> <p>Station KE</p> <p>Station KF</p> <p>Station KG</p> <p>Station KH</p> <p>Station KI</p> <p>Station KJ</p> <p>Station KK</p> <p>Station KL</p> <p>Station KM</p> <p>Station KN</p> <p>Station KO</p> <p>Station KP</p> <p>Station KQ</p> <p>Station KR</p> <p>Station KS</p> <p>Station KT</p> <p>Station KU</p> <p>Station KV</p> <p>Station KW</p> <p>Station KX</p> <p>Station KY</p> <p>Station KZ</p> <p>Station LA</p> <p>Station LB</p> <p>Station LC</p> <p>Station LD</p> <p>Station LE</p> <p>Station LF</p> <p>Station LG</p> <p>Station LH</p> <p>Station LI</p> <p>Station LJ</p> <p>Station LK</p> <p>Station LL</p> <p>Station LM</p> <p>Station LN</p> <p>Station LO</p> <p>Station LP</p> <p>Station LQ</p> <p>Station LR</p> <p>Station LS</p> <p>Station LT</p> <p>Station LU</p> <p>Station LV</p> <p>Station LW</p> <p>Station LX</p> <p>Station LY</p> <p>Station LZ</p> <p>Station MA</p> <p>Station MB</p> <p>Station MC</p> <p>Station MD</p> <p>Station ME</p> <p>Station MF</p> <p>Station MG</p> <p>Station MH</p> <p>Station MI</p> <p>Station MJ</p> <p>Station MK</p> <p>Station ML</p> <p>Station MM</p> <p>Station MN</p> <p>Station MO</p> <p>Station MP</p> <p>Station MQ</p> <p>Station MR</p> <p>Station MS</p> <p>Station MT</p> <p>Station MU</p> <p>Station MV</p> <p>Station MW</p> <p>Station MX</p> <p>Station MY</p> <p>Station MZ</p> <p>Station NA</p> <p>Station NB</p> <p>Station NC</p> <p>Station ND</p> <p>Station NE</p> <p>Station NF</p> <p>Station NG</p> <p>Station NH</p> <p>Station NI</p> <p>Station NJ</p> <p>Station NK</p> <p>Station NL</p> <p>Station NM</p> <p>Station NN</p> <p>Station NO</p> <p>Station NP</p> <p>Station NQ</p> <p>Station NR</p> <p>Station NS</p> <p>Station NT</p> <p>Station NU</p> <p>Station NV</p> <p>Station NW</p> <p>Station NX</p> <p>Station NY</p> <p>Station NZ</p> <p>Station OA</p> <p>Station OB</p> <p>Station OC</p> <p>Station OD</p> <p>Station OE</p> <p>Station OF</p> <p>Station OG</p> <p>Station OH</p> <p>Station OI</p> <p>Station OJ</p> <p>Station OK</p> <p>Station OL</p> <p>Station OM</p> <p>Station ON</p> <p>Station OO</p> <p>Station OP</p> <p>Station OQ</p> <p>Station OR</p> <p>Station OS</p> <p>Station OT</p> <p>Station OU</p> <p>Station OV</p> <p>Station OW</p> <p>Station OX</p> <p>Station OY</p> <p>Station OZ</p> <p>Station PA</p> <p>Station PB</p> <p>Station PC</p> <p>Station PD</p> <p>Station PE</p> <p>Station PF</p> <p>Station PG</p> <p>Station PH</p> <p>Station PI</p> <p>Station PJ</p> <p>Station PK</p> <p>Station PL</p> <p>Station PM</p> <p>Station PN</p> <p>Station PO</p> <p>Station PP</p> <p>Station PQ</p> <p>Station PR</p> <p>Station PS</p> <p>Station PT</p> <p>Station PU</p> <p>Station PV</p> <p>Station PW</p> <p>Station PX</p> <p>Station PY</p> <p>Station PZ</p> <p>Station QA</p> <p>Station QB</p> <p>Station QC</p> <p>Station QD</p> <p>Station QE</p> <p>Station QF</p> <p>Station QG</p> <p>Station QH</p> <p>Station QI</p> <p>Station QJ</p> <p>Station QK</p> <p>Station QL</p> <p>Station QM</p> <p>Station QN</p> <p>Station QO</p> <p>Station QP</p> <p>Station QQ</p> <p>Station QR</p> <p>Station QS</p> <p>Station QT</p> <p>Station QU</p> <p>Station QV</p> <p>Station QW</p> <p>Station QX</p> <p>Station QY</p> <p>Station QZ</p> <p>Station RA</p> <p>Station RB</p> <p>Station RC</p> <p>Station RD</p> <p>Station RE</p> <p>Station RF</p> <p>Station RG</p> <p>Station RH</p> <p>Station RI</p> <p>Station RJ</p> <p>Station RK</p> <p>Station RL</p> <p>Station RM</p> <p>Station RN</p> <p>Station RO</p> <p>Station RP</p> <p>Station RQ</p> <p>Station RR</p> <p>Station RS</p> <p>Station RT</p> <p>Station RU</p> <p>Station RV</p> <p>Station RW</p> <p>Station RX</p> <p>Station RY</p> <p>Station RZ</p> <p>Station SA</p> <p>Station SB</p> <p>Station SC</p> <p>Station SD</p> <p>Station SE</p> <p>Station SF</p> <p>Station SG</p> <p>Station SH</p> <p>Station SI</p> <p>Station SJ</p> <p>Station SK</p> <p>Station SL</p> <p>Station SM</p> <p>Station SN</p> <p>Station SO</p> <p>Station SP</p> <p>Station SQ</p> <p>Station SR</p> <p>Station SS</p> <p>Station ST</p> <p>Station SU</p> <p>Station SV</p> <p>Station SW</p> <p>Station SX</p> <p>Station SY</p> <p>Station SZ</p> <p>Station TA</p> <p>Station TB</p> <p>Station TC</p> <p>Station TD</p> <p>Station TE</p> <p>Station TF</p> <p>Station TG</p> <p>Station TH</p> <p>Station TI</p> <p>Station TJ</p> <p>Station TK</p> <p>Station TL</p> <p>Station TM</p> <p>Station TN</p> <p>Station TO</p> <p>Station TP</p> <p>Station TQ</p> <p>Station TR</p> <p>Station TS</p> <p>Station TT</p> <p>Station TU</p> <p>Station TV</p> <p>Station TW</p> <p>Station TX</p> <p>Station TY</p> <p>Station TZ</p> <p>Station UA</p> <p>Station UB</p> <p>Station UC</p> <p>Station UD</p> <p>Station UE</p> <p>Station UF</p> <p>Station UG</p> <p>Station UH</p> <p>Station UI</p> <p>Station UJ</p> <p>Station UK</p> <p>Station UL</p> <p>Station UM</p> <p>Station UN</p> <p>Station UO</p> <p>Station UP</p> <p>Station UQ</p> <p>Station UR</p> <p>Station US</p> <p>Station UT</p> <p>Station UY</p> <p>Station UZ</p> <p>Station VA</p> <p>Station VB</p> <p>Station VC</p> <p>Station VD</p> <p>Station VE</p> <p>Station VF</p> <p>Station VG</p> <p>Station VH</p> <p>Station VI</p> <p>Station VJ</p> <p>Station VK</p> <p>Station VL</p> <p>Station VM</p> <p>Station VN</p> <p>Station VO</p> <p>Station VP</p> <p>Station VQ</p> <p>Station VR</p> <p>Station VS</p> <p>Station VT</p> <p>Station VY</p> <p>Station VZ</p> <p>Station WA</p> <p>Station WB</p> <p>Station WC</p> <p>Station WD</p> <p>Station WE</p> <p>Station WF</p> <p>Station WG</p> <p>Station WH</p> <p>Station WI</p> <p>Station WJ</p> <p>Station WK</p> <p>Station WL</p> <p>Station WM</p> <p>Station WN</p> <p>Station WO</p> <p>Station WP</p> <p>Station WQ</p> <p>Station WR</p> <p>Station WS</p> <p>Station WT</p> <p>Station WY</p> <p>Station WZ</p> <p>Station XA</p> <p>Station XB</p> <p>Station XC</p> <p>Station XD</p> <p>Station XE</p> <p>Station XF</p> <p>Station XG</p> <p>Station XH</p> <p>Station XI</p> <p>Station XJ</p> <p>Station XK</p> <p>Station XL</p> <p>Station XM</p> <p>Station XN</p> <p>Station XO</p> <p>Station XP</p> <p>Station XQ</p> <p>Station XR</p> <p>Station XS</p> <p>Station XT</p> <p>Station XY</p> <p>Station XZ</p> <p>Station YA</p> <p>Station YB</p> <p>Station YC</p> <p>Station YD</p> <p>Station YE</p> <p>Station YF</p> <p>Station YG</p> <p>Station YH</p> <p>Station YI</p> <p>Station YJ</p> <p>Station YK</p> <p>Station YL</p> <p>Station YM</p> <p>Station YN</p> <p>Station YO</p> <p>Station YP</p> <p>Station YQ</p> <p>Station YR</p> <p>Station YS</p> <p>Station YT</p> <p>Station YY</p> <p>Station YZ</p> <p>Station ZA</p> <p>Station ZB</p> <p>Station ZC</p> <p>Station ZD</p> <p>Station ZE</p> <p>Station ZF</p> <p>Station ZG</p> <p>Station ZH</p> <p>Station ZI</p> <p>Station ZJ</p> <p>Station ZK</p> <p>Station ZL</p> <p>Station ZM</p> <p>Station ZN</p> <p>Station ZO</p> <p>Station ZP</p> <p>Station ZQ</p> <p>Station ZR</p> <p>Station ZS</p> <p>Station ZT</p> <p>Station ZY</p> <p>Station ZZ</p> |
|   |   |   | <b>Total</b>                                                                                                                                   | <b>10</b>           | <p>In Exemplar 3, this candidate makes an excellent attempt at every portion of the question. They have taken great effort to make themselves clear with technical language. They have also performed numerous calculations to compare the GPE and KE in the two different scenarios.</p> <p>A further figure appears right at the bottom of the response. The candidate has correctly calculated the percentage of the overall energy required that is supplied by either method.</p> <p>In conclusion, the candidate has used their many correct calculations to weigh up evidence effectively in terms of the advantages and limitations.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 3 | a | i | <p>Curve starts at (0,0) with gradient decreasing to a maximum value</p> <p>30 on vertical axis matching highest point of candidate's line</p> | <p>B1</p> <p>B1</p> | <p>Accept horizontal asymptote</p> <p>NB ignore candidate's response after their line reaches 30 (m/s)</p> <p><b>Examiner's Comments</b></p> <p>Most candidates used the grid effectively to put a suitable scale on the speed axis. They also communicated that the maximum speed was <math>30 \text{ m s}^{-1}</math>. Many candidates also got the shape of the curve correct,</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             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|--|--|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  |  |     |                                                                                                                                                                         |                | which starts with maximum gradient and then flattens out.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|  |  | ii  | Resistive force increases (with speed)<br>Zero net or zero resultant force                                                                                              | B1<br>B1       | <p>Allow drag / (air) resistance / friction for 'resistive force'</p> <p>Allow resistive force = component of weight down the slope</p> <p>NOT simply idea of resistive force = weight</p> <p><b><u>Examiner's Comments</u></b></p> <p>While many candidates appreciated that the car reached a maximum speed because the resultant force was zero, some contradicted this by saying that the weight = drag (as it would be in vertical motion) or something else incorrect. Far fewer candidates stated that the drag increases with speed effectively. Quoting the given expression <math>F = kv^2</math> was deemed insufficient.</p> <p><b>Examination Tip</b></p> <p>Repeating information given in the question is rarely creditworthy by itself.</p> |
|  |  | iii | <p>Component of weight down slope = <math>9300 \sin 5^\circ</math></p> <p>Re-arrange to <math>(k=)F \div v^2</math></p> <p><math>(k=)810 \div 900 = 0.9\dots</math></p> | M1<br>M1<br>A1 | <p>Allow 810 or 811 seen</p> <p>Allow substitutions for variables</p> <p>Mark is for substitution <u>and</u> candidate's value seen</p> <p><b><u>Examiner's Comments</u></b></p> <p>As this question is a 'show that', all steps were required. Many candidates omitted the rearrangement stage, restricting their maximum score for this item to 1 mark. This approach was consistent throughout the paper for this type of question.</p> <p><b>Examination Tip</b></p> <p>Make sure that all steps of working are presented in 'show that' questions, especially the step that shows the relevant quantity as the subject of the equation. Always show your evaluation</p>                                                                                |



|   |   |   |                                                                                                                                                                                                                                                                                                                                                     |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---|---|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   |   |   |                                                                                                                                                                                                                                                                                                                                                     |                         | to at least 1 more significant figure than that shown in the question.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|   | b |   | <p>evidence of substitution of <math>F=kv^2</math> into <math>P = Fv</math></p> <p><math>v = (P \div k)^{1/3}</math></p> <p><math>v = 44 \text{ (m s}^{-1}\text{)}</math></p>                                                                                                                                                                       | <p>C1<br/>C1<br/>A1</p> | <p>e.g. <math>P = kv^3</math>, <math>P = (kv^2) v</math>, etc</p> <p>Allow use of <math>k = 1</math> which gives 42</p> <p>Allow answer within range 36 to 53</p> <p><b><u>Examiner's Comments</u></b></p> <p>The key idea here is that the force from the engine (given by <math>F = P / v</math>) will equal the resistive forces (<math>F = kv^2</math>) when the car is at maximum speed. Candidates could choose which value of <math>k</math> they used here, either <math>k = 1</math> from the question data or the value of <math>k</math> from the previous item. This gives an acceptable range of speeds as stated in the mark scheme.</p> |
|   | c |   | <p>Power is proportional to the speed cubed /</p> <p>Max speed is proportional to the cube root of max power /</p> <p>power proportional to speed <math>\times kv^2</math></p> <p>Valid reference to the cube root of 2 increase in velocity for double power /</p> <p>Valid reference to factor of 8 increase in power for double the velocity</p> | <p>B1<br/>B1</p>        | <p>NB cube root of 2 is 1.2599... e.g. <math>1.26 \times 44 = 55 \text{ (m s}^{-1}\text{)}</math></p> <p><b><u>Examiner's Comments</u></b></p> <p>Even if they couldn't complete the calculation in the previous item, candidates needed to be able to state the idea qualitatively for the first mark. No further calculations were required, except the correct answer that the maximum speed would increase by a factor of cube root (2).</p>                                                                                                                                                                                                       |
|   |   |   | <b>Total</b>                                                                                                                                                                                                                                                                                                                                        | <b>12</b>               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 4 |   | i | <p>Horizontal = <math>43 \text{ (.3) (m s}^{-1}\text{)}</math></p> <p>Vertical = <math>25 \text{ (m s}^{-1}\text{)}</math></p>                                                                                                                                                                                                                      | <p>B1<br/>B1</p>        | <p>ignore sign</p> <p>Allow answers in incorrect order for 1 mark MAX</p> <p>Allow <math>H = 7.7 \text{ (m s}^{-1}\text{)}</math>, <math>V = -49.4 \text{ (m s}^{-1}\text{)}</math> 1 mark MAX</p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates got this correct. Some scored a single mark for confusing sine and cosine but otherwise completing the calculation correctly.</p> <p><b>Examination Tip</b></p> <p>Make sure to check whether your calculator should be in degrees or</p>                                                                                                                                               |

|   |  |     |                                                                                                                                                                                                    |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---|--|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   |  |     |                                                                                                                                                                                                    |                         | <p>radians mode.</p> <p>Also, practise which trigonometric function to use. If in doubt, draw a labelled right-angled triangle to help identify the correct function.</p>                                                                                                                                                                                                                                                                                                                                                                                      |
|   |  | ii  | <p>Correct application of N3L</p> <p>Plus ONE from:</p> <p>(Direction of) momentum of air has changed or direction of air flow has changed</p> <p>There is a force on the air (from the model)</p> | <p>B1<br/>B1<br/>B1</p> | <p>force on air is equal (and opposite) to force on model</p> <p><b><u>Examiner's Comments</u></b></p> <p>The key idea here was Newton's third law, with credit for some supporting information.</p>                                                                                                                                                                                                                                                                                                                                                           |
|   |  | iii | $F = \frac{\Delta p}{\Delta t}$ <p><math>F = 35 \times 25</math> (divided by 1)<br/> <math>F = 880</math> (N)</p>                                                                                  | <p>C1<br/>C1<br/>A1</p> | <p>ecf candidate's vertical velocity in (i)<br/>         Allow 875<br/>         Allow 870</p> <p><b><u>Examiner's Comments</u></b></p> <p>Answers that clearly used <math>F = ma</math> with the acceleration of <math>25 \text{ ms}^{-2}</math> were deemed wrong Physics (as in previous series). Error Carried Forward (ECF) was clearly applied here also.</p>                                                                                                                                                                                             |
|   |  |     | <b>Total</b>                                                                                                                                                                                       | <b>7</b>                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 5 |  |     | <p>Similarity: same magnitude or same speed or (still) <math>0.17 \text{ (m s}^{-1}\text{)}</math></p> <p>Difference: (different) direction or (approximately) opposite direction</p>              | <p>B1<br/>B1</p>        | <p><b>Allow ECF</b> from (a) for 0.17<br/> <b>Not</b> same velocity</p> <p><b>Allow</b> negative</p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates understood that velocity was a vector quantity and there were many correct answers explaining the similarity in that the magnitude of the velocity was the same and the difference was the direction.</p> <p>Lower scoring candidates often stated that the velocity was the same. This suggests that there was not the full understanding of the physical quantities speed and velocity.</p> |
|   |  |     | <b>Total</b>                                                                                                                                                                                       | <b>2</b>                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

|   |   |                                                                                                                                                                                                                                                                                                                                            |                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6 | a | $22.3 \cos 84 (= 2.33)$<br>2.33                                                                                                                                                                                                                                                                                                            | M1<br>A0                         | <p><b>ALLOW</b> <math>22.3 \sin 6</math></p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates clearly showed how the initial velocity of the ball could be resolved into its horizontal component. Most candidates used <math>\cos 84^\circ</math> although there was a significant minority who correctly used <math>\sin 6^\circ</math>.</p>                                                                                                                                                                                                                                                                                              |
|   | b | $v_v^2 = 2.33^2 + 2 \times 9.81 \times 2.4$<br>$v_v = \sqrt{52.517}$ OR 7.247<br>7.25                                                                                                                                                                                                                                                      | M1<br>M1<br>A0                   | <p><b>ALLOW ECF</b> from (a)</p> <p><b><u>Examiner's Comments</u></b></p> <p>For this part of the question it was necessary for candidates to clearly show the substitution of the data into the equation. This includes the value of <math>g</math> (as <math>9.81 \text{ m s}^{-2}</math>) from the data sheet. It was also necessary for candidates to show that having determined <math>v^2</math>, this value needed to have the square root taken. Higher performing candidates wrote the final answer as 7.247 or <math>7.24685 \approx 7.25 \text{ (m s}^{-1}\text{)}</math>.</p>                                                              |
|   | c | $u_h = 22.3 \sin 84 = 22.2$<br>$v = \sqrt{22.2^2 + 7.25^2} = 23.35$<br>$(= \frac{1}{2} \times 0.210 \times 23.35^2) = 57.2 \text{ (J)}$<br>OR<br>Change in potential energy = $0.210 \times 9.81 \times 2.40 = 4.94$<br>Initial kinetic energy = $\frac{1}{2} \times 0.21 \times 22.3^2$ OR 52.2 (J)<br>$(4.94 + 52.2 =) 57.1 \text{ (J)}$ | C1<br>C1<br>A1<br>C1<br>C1<br>A1 | <p><b>ALLOW</b> <math>v^2 = 545</math><br/> <b>ALLOW</b> 57.2 (J)</p> <p><b><u>Examiner's Comments</u></b></p> <p>This question proved challenging to candidates. The common error was to calculate the kinetic energy using a value of <math>7.25 \text{ m s}^{-1}</math>.</p> <p>There were two main methods of answering this question:</p> <p>Either:</p> <p>determining the horizontal component of the velocity of the ball, (which remains constant)</p> <p>then working out the resultant velocity of the ball as it hits the ground</p> <p>and then calculate the kinetic energy.</p> <p>Or:</p> <p>Calculate the change in gravitational</p> |

|   |   |    |                                                                                                                                                                                                                                                                                                                             |                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---|---|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   |   |    |                                                                                                                                                                                                                                                                                                                             |                                              | <p>potential energy</p> <p>Calculate the initial kinetic energy of the ball</p> <p>And then add the two values together.</p> <p> <b>Misconception</b></p> <p>Omitting the kinetic energy in the horizontal direction when calculating the kinetic energy of the ball.</p> <p>Candidates should be able to compare the motion of a projectile in two perpendicular directions and also confirm that similar results are obtained by considering energy transfers.</p> |
|   | d |    | <p>(change of) Momentum = mass<br/>×(change of) velocity<br/>As velocity increases, the momentum increases<br/>OR<br/>force = rate of change of momentum<br/>gravitational force acts on the ball and increases momentum<br/>OR<br/>Momentum is a vector quantity, change in direction means that the momentum changes.</p> | <p>M1<br/>A1<br/>M1<br/>A1<br/>M1<br/>A1</p> | <p><b>ALLOW</b> changes for increases</p> <p><b><u>Examiner's Comments</u></b></p> <p>There are many possible explanations as to why the momentum of the ball changes. To score full marks candidates needed to state a property of momentum, e.g. momentum = mass × velocity before then explaining why the momentum would change, e.g. as the ball falls, velocity increases so for constant mass the momentum increases.</p>                                                                                                                        |
|   |   |    | <b>Total</b>                                                                                                                                                                                                                                                                                                                | <b>8</b>                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 7 |   | i  | <p>newton in base units is <math>\text{kg m s}^{-2}</math></p> <p>Substitution and cancelling of kg and m arriving at <math>\text{s}^2 \rightarrow \text{s}^2</math></p>                                                                                                                                                    | <p>C1<br/>A1</p>                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|   |   | ii | <p>One force is increased by <math>kx</math> and one is reduced by <math>kx</math> /AW</p> <p>Some working to include <math>kx - (-kx)</math></p>                                                                                                                                                                           | <p>B1<br/>B1</p>                             | <p>reject 2 springs in series or 2 springs in parallel idea XP<br/>accept one extension is reduced by <math>x</math> and one is increased by <math>x</math> / AW</p> <p><b><u>Examiner's Comments</u></b></p> <p>Question 21 (a) (ii) is considerably more challenging. The two springs are not in series nor are they in parallel.</p>                                                                                                                                                                                                                |

|   |   |     |                                                                              |                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
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|   |   |     |                                                                              |                  | <p>When there is a displacement <math>x</math> one spring is extended by an <i>extra</i> amount <math>x</math> i.e. an extension of <math>(e + x)</math> and the other is extended by a reduced amount <math>x</math> i.e. an extension of <math>(e - x)</math> where <math>e</math> is the equilibrium extension. This meant that the resultant force was <math>k(e + x) - k(e - x)</math>, which is clearly <math>2kx</math>.</p> <p>Neither spring goes into compression, although we condoned candidates who suggested that a reduction in extension meant the same as a compression.</p>                                                                                                          |
|   |   | iii | <p>period is independent of <u>amplitude</u> / AW</p> <p>No effect</p>       | <p>M1<br/>A1</p> | <p>Allow isochronous</p> <p><b><u>Examiner's Comments</u></b></p> <p>A reasonably large proportion of candidates did not link the idea of initial displacement to the amplitude of this motion. Those that did often scored both marks as they also recalled that SHM is isochronous.</p> <p> <b>Assessment for learning</b></p> <p>Merely repeating the words in the question, in this case 'the initial displacement' instead of 'amplitude', is unlikely to give access to full marks. Think about which piece or pieces of technical language on the specification are the likely target of each question.</p> |
|   |   |     | <b>Total</b>                                                                 | <b>6</b>         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 8 | a | i   | <p>Arrow <b>along</b> the line of the support rod labelled tension or T.</p> | <p>B1</p>        | <p>Allow unlabelled single arrow along either rod<br/>Allow unlabelled arrows along both rods<br/>Allow arrow(s) up, down or both</p> <p>NOT any contradictory arrows</p> <p><b><u>Examiner's Comments</u></b></p> <p>In Question 17 (a) (i) of this question, the phrase 'tension in the rod' can mean several different things, all of which were given in the mark scheme.</p>                                                                                                                                                                                                                                                                                                                      |

|  |  |     |                                                                                                                                                                             |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--|--|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  |  | ii  | <p>11.1 sin 35 or 11.1 cos 55 seen</p> <p>addition of 3.9 (half the diameter of the support disc) to candidate's horizontal component of rod length</p> <p>Total= 10.3m</p> | <p>M1<br/>M1<br/>A0</p> | <p>NOT use of tan 35 or tan 55</p> <p>allow 7.8/2 for 3.9</p> <p>10.27 to 2 dp</p> <p>NB use of 11.1 cos 35 or 11.1 sin 55 arriving at 12.99 scores 1 (wrong trig)<br/>NB reject use of radians (scores 0)</p> <p><b><u>Examiner's Comments</u></b></p> <p>Many candidates approached part (ii) with some confidence, spotting that the horizontal portion of the rod was 11.1 sin(35) and that it should be added to the radius of the disc.</p>                                                                                       |
|  |  | iii | <p><math>mg = T \cos 35</math></p> <p><math>T = mg \div \cos 35</math><br/>= 140 N</p>                                                                                      | <p>C1<br/>C1<br/>A1</p> | <p>Allow use of sin 55<br/>NOT use of tan 35 or tan 55</p> <p>Answer is 143.7 N to 4 sf</p> <p><b><u>Examiner's Comments</u></b></p> <p>Parts (a) (iii) and (iv) were more challenging, requiring good knowledge of both circular motion and how to calculate components of forces. Again there were several legitimate routes to the right answer, all of which were mentioned in the mark scheme. Very logical approaches were in part (a) (iii), to equate the vertical component of the tension with the weight of the sandbag.</p> |
|  |  | iv  | <p><math>T \sin 35 = mr\omega^2</math></p> <p><math>\omega = \sqrt{\frac{T \sin 35}{mr}}</math></p> <p>=0.8(17) radian s<sup>-1</sup></p>                                   | <p>M1<br/>A1<br/>A0</p> | <p>Allow use of <math>W \tan 35</math> or <math>W \tan 55</math><br/>Allow use of cos 55 and/or <math>mv^2/r</math><br/>Allow use of Pythagoras to find centripetal force (82.4...)<br/>NOT use of <math>T \tan 35</math> or <math>T \tan 55</math></p> <p>Allow <math>\omega^2</math> subject.</p> <p>Allow any combination of rearrangement and substitution</p> <p>ECF allowed for T and r.<br/>Use of 2 s.f. values for T and r gives 0.84 m</p> <p><b><u>Examiner's Comments</u></b></p>                                           |

|  |   |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--|---|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  |   |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         | In part (a) (iv), the quickest approach was to equate the horizontal component of the tension with the centripetal force. The data booklet provides a convenient expression for the centripetal force in terms of the angular velocity, without the need for finding the tangential velocity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|  | b | i   | <p>Use of <math>17 = \frac{1}{2}gt^2</math></p> <p><math>= 1.9 \text{ (1.86) s}</math></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <p>C1<br/>A1</p>        | <p>i.e. substitution of 17 and g or 9.81 or 9.8</p> <p>e.g.<br/> <math>s = (ut) + \frac{1}{2}at^2</math></p> $t = \sqrt{\frac{2s}{a}}$ $= \sqrt{\frac{2 \times 17}{9.81}}$ <p>Allow any subject</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|  |   | ii  | <p>Horizontal speed = <math>\omega r</math> or Horizontal distance = speed <math>\times</math> time</p> <p><math>= 0.82 \text{ radians s}^{-1} \times 10.26 \text{ m} \times 1.86 \text{ s}</math></p> <p><math>= 16 \text{ m (15.6 m)}</math></p>                                                                                                                                                                                                                                                                                                                                  | <p>C1<br/>C1<br/>A1</p> | <p>Use of data in the question stem (0.8 and 10) allowed, which gives 15.2 m.</p> <p>Ecf for use of candidate's value of r and <math>\omega</math>, giving</p> <p>values rounding to between 14.9 and 16.0 m</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|  |   | iii | <p>Relevant variable identified</p> <p>Effect on speed of shoe or time of flight of shoe correctly identified</p> <p>Conclusion consistent with relevant physics</p> <p>e.g.</p> <ul style="list-style-type: none"> <li>Shoe is lower mass yet no change in angular velocity or radius since independent of mass so no change in horizontal displacement.</li> <li>Shoe is below seat so would be travelling with larger radius/speed so larger distance travelled horizontally</li> <li>Shoe might have been kicked off backwards so have lower speed so lower distance</li> </ul> | <p>M1<br/>M1<br/>A1</p> | <p>e.g. mass/weight, drag/air resistance, radius, height, starting condition (e.g. kicking shoe off) Assume "it" in response refers to the shoe. ignore velocity for first M1 allow correct explanation of "no effect" on speed or time by change of mass</p> <p><b><u>Examiner's Comments</u></b></p> <p>Question 17 (b) explored ideas about parabolic flight due to gravitation. The only force acting on the sandbag and the shoe after they have been released is the weight force, which acts vertically downwards.</p> <p>Many candidates realised that the vertical velocity of the sandbag when it left the swing was zero, enabling them to calculate the time for the bag to fall 17m vertically downwards (using <math>s = \frac{1}{2}gt^2</math>)</p> |

|    |  |  |                                                                                                                                                                                                                                                                                                                                         |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----|--|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |  |  | <ul style="list-style-type: none"> <li>Shoe would come from below the seat/lower than the sandbag i.e. vertical distance to fall less, thus time of flight and horizontal distance less.</li> <li>Effect of air resistance hadn't been included so shoe suffers drag, decelerating horizontally so distance would be smaller</li> </ul> |           | <p>To calculate the horizontal distance travelled required both the horizontal velocity (from <math>v = r\omega</math>) and the time of flight from part (b) (iii). There was lots of scope for applying error carried forward rules as mentioned in the mark scheme.</p> <p> <b>Misconception</b></p> <p>In lots of questions, candidates make assumptions when trying to use formulae to justify their ideas. In this case, it was that for the same radius, the shoe must leave the seat faster than the sandbag, purely because the shoe had less mass.</p> <p>Often, what is constant is as important to consider as what is changing. Here, if the radius for the sandbag and the shoe are the same, then the horizontal velocity at release must be the same, since the radius and angular speed for both are the same, using <math>v = r\omega</math>.</p> |
|    |  |  | <b>Total</b>                                                                                                                                                                                                                                                                                                                            | <b>16</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 9  |  |  | C                                                                                                                                                                                                                                                                                                                                       | 1         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|    |  |  | <b>Total</b>                                                                                                                                                                                                                                                                                                                            | <b>1</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 10 |  |  | B                                                                                                                                                                                                                                                                                                                                       | 1         | <p><b><u>Examiner's Comments</u></b></p> <p>This question was generally answered well as most candidates correctly resolved <math>T</math>, tension to determine an expression for <math>W</math>.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|    |  |  | <b>Total</b>                                                                                                                                                                                                                                                                                                                            | <b>1</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 11 |  |  | C                                                                                                                                                                                                                                                                                                                                       | 1         | <p><b><u>Examiner's Comments</u></b></p> <p>The first step with this question is to calculate the resultant force, which is 0.2 N upwards (eliminating option A). As the drag force is upwards, the direction of motion must be downwards (eliminating option D). Since the</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |



|    |  |    |                                                                                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----|--|----|--------------------------------------------------------------------------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |  |    |                                                                                            |                | resultant is opposite to the direction of travel, this object must be decelerating.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|    |  |    | <b>Total</b>                                                                               | <b>1</b>       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 12 |  |    | <b>B</b>                                                                                   | 1              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|    |  |    | <b>Total</b>                                                                               | <b>1</b>       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 13 |  |    | <b>D</b>                                                                                   | 1              | <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates got this correct by correctly identifying mass as a scalar and force as a vector. The most likely incorrect answer was C.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|    |  |    | <b>Total</b>                                                                               | <b>1</b>       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 14 |  | i  | $a = \frac{6.0}{3.0}$<br>2.0                                                               | C1<br>A0       | <p><b>Allow</b> any correct gradient calculation</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates had to show that the acceleration was <math>2.0 \text{ m s}^{-2}</math> which 90% of candidates demonstrated successfully by using values from the graph and calculating a gradient value which equalled the acceleration. To be given this mark, candidates had to clearly show their working out using values taken from the graph.</p>                                                                                                                                                                                                                                                              |
|    |  | ii | $680\cos 55 / 150 \times 2.0$<br>$680\cos 55 - R = 150 \times 2.0$<br>$R = 90 \text{ (N)}$ | C1<br>C1<br>A1 | <p>If both components given (vertical and horizontal) it must be clear that the 390N is the horizontal component.</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates performed less well on this question as it was mostly only the most successful responses that were given 3 marks for resolving the horizontal component of the tension in the rope to correctly calculate the horizontal resistance <math>R</math>. About 40% of candidates were given 1 mark for either correctly resolving the horizontal component of the tension to give 390 N or calculating the resultant force (<math>F = ma</math>) to give 300 N. It would have helped candidates understand the question to draw a free</p> |

|    |   |    |                                                                                                                                                |              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
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|    |   |    |                                                                                                                                                |              | body force diagram to identify the forces acting on the buggy and direction and magnitude of the resultant force.                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|    |   |    | <b>Total</b>                                                                                                                                   | <b>4</b>     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 15 | a | i  | $E_p (= 0.16 \times 9.81 \times 2.5) = 3.9 \text{ (J)}$                                                                                        | A1           | 3.924<br><br><b><u>Examiner's Comments</u></b><br><br>This question was generally answered well.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|    |   | ii | $v^2 = \frac{2 \times 3.9}{0.16}$ or 48.75 OR $v^2 = 2 \times 9.81 \times 2.5$ or 49.05<br><br>$v = 7.0 \text{ (ms}^{-1}\text{)}$              | C1<br><br>A1 | <b>Allow ECF</b> from (a)(i)<br><br><b>Allow 1sf</b><br><br><b><u>Examiner's Comments</u></b><br><br>Most candidates correctly equated the change in gravitational potential energy to kinetic energy and gained the correct answer. Other candidates correctly used $v^2 = 2 gh$ .<br><br>A number of candidates gave the answer as 7 (ms <sup>-1</sup> ) – since the data in the question was given to two significant figures the answers should also be given to two significant figures.<br><br>Ideally the substitution of data into appropriate equations should be shown. |
|    | b | i  | $R (= 12 \times 0.71) = 8.5(2) \text{ (m)}$                                                                                                    | A1           | <b><u>Examiner's Comments</u></b><br><br>It was expected that candidates would multiply the horizontal velocity by the time. This was generally answered well.<br><br> <b>Assessment for learning</b><br><br>When considering projectile motion, candidates should treat the vertical and horizontal velocities independently.                                                                                                                                                                |
|    |   | ii | $E_k = \frac{1}{2} \times 0.16 \times 12^2$ or 11.5<br>OR<br>$= \frac{1}{2} \times 0.16 \times 13.9^2$ or $\frac{1}{2} \times 0.16 \times 193$ | C1           | <b>Allow</b> use of vertical $v = 6.97$ (calculated using $v = u + at$ ;) )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

|  |  |     |                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                         |
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|  |  |     | $E_k (= 11.5 + (a)(i) = 11.5 + 3.9) = 15(.4) \text{ (J)}$                                                                | <p>A1</p> <p><b>Allow</b> 15.5 (J)<br/> <b>Allow ECF</b> from (a)(i)</p> <p><b><u>Examiner's Comments</u></b></p> <p>Many candidates calculated the kinetic energy of the ball using the velocity of the ball in the horizontal direction but then did not add the change in potential energy of the ball as it fell.</p> <p>Other candidates determined the resultant velocity of the ball and then calculated the kinetic energy.</p> |
|  |  | iii | $\theta \left( = \tan^{-1} \left( \frac{(a)(ii)}{12} \right) = \tan^{-1} \left( \frac{7}{12} \right) \right) = 30^\circ$ | <p>A1</p> <p><b>Allow</b> ECF from (a)(ii)<br/> 30.256</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates achieving on this question correctly determined the angle using the horizontal and vertical velocities.</p> <p>Where the response was incorrect, candidates had used either energies or distances.</p>                                                                                                                |
|  |  |     | <b>Total</b>                                                                                                             | <b>7</b>                                                                                                                                                                                                                                                                                                                                                                                                                                |