

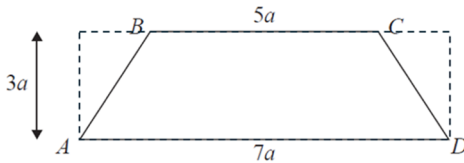
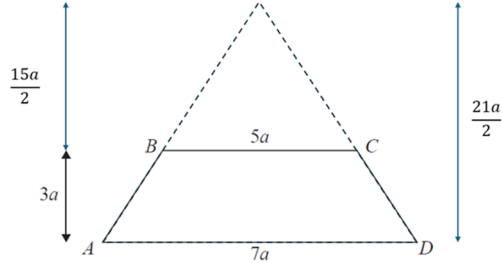
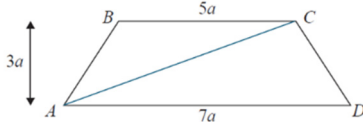
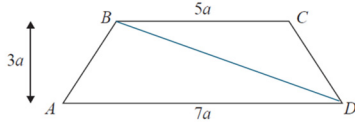
| Question    | Scheme                                                                                                                                                                                                                                                                                                                                                                                                                 | Marks       |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| <b>1(a)</b> | Use $\mathbf{r} = \int \mathbf{v} dt$                                                                                                                                                                                                                                                                                                                                                                                  | M1          |
|             | Correct integration<br>Eg $(t^3 + 6t^2 + 12t)\mathbf{i} + \left(\frac{5}{3}t^3 + 5t^2\right)\mathbf{j} + (C)$<br>Or $(t+2)^3\mathbf{i} + \left(\frac{5}{3}t^3 + 5t^2\right)\mathbf{j} + (K)$                                                                                                                                                                                                                           | A1          |
|             | Complete method using $t = 0, \mathbf{r} = -30\mathbf{i} - 45\mathbf{j}(\text{m})$ and substitute $t = 3$<br>Indefinite integration<br>Use of $t = 0, \mathbf{r} = -30\mathbf{i} - 45\mathbf{j}(\text{m})$ to find constant of integration and substitute $t = 3$ .<br>Definite integration<br>Use of $\mathbf{r} = (-30\mathbf{i} - 45\mathbf{j}) + \int_0^3 \mathbf{v} dt$                                           | DM1         |
|             | $\mathbf{r} = 87\mathbf{i} + 45\mathbf{j}(\text{m})$                                                                                                                                                                                                                                                                                                                                                                   | A1          |
|             |                                                                                                                                                                                                                                                                                                                                                                                                                        | (4)         |
| <b>1(b)</b> | Use $\mathbf{a} = \frac{d\mathbf{v}}{dt}$                                                                                                                                                                                                                                                                                                                                                                              | M1          |
|             | Correct differentiation<br>$\mathbf{a} = (6t + 12)\mathbf{i} + (10t + 10)\mathbf{j}$                                                                                                                                                                                                                                                                                                                                   | A1          |
|             | Substitute $t = 3$ and find magnitude                                                                                                                                                                                                                                                                                                                                                                                  | DM1         |
|             | $ \mathbf{a}  = 50 (\text{m s}^{-2})$                                                                                                                                                                                                                                                                                                                                                                                  | A1          |
|             |                                                                                                                                                                                                                                                                                                                                                                                                                        | (4)         |
| <b>1(c)</b> | $3(T+2)^2 = 10T(T+2)$<br>$(3T+6=10T) \quad (7T^2+8T-12=0)$                                                                                                                                                                                                                                                                                                                                                             | M1          |
|             | $T = \frac{6}{7}$                                                                                                                                                                                                                                                                                                                                                                                                      | A1          |
|             |                                                                                                                                                                                                                                                                                                                                                                                                                        | (2)         |
|             |                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>(10)</b> |
|             | <b>Notes</b>                                                                                                                                                                                                                                                                                                                                                                                                           |             |
| <b>1(a)</b> |                                                                                                                                                                                                                                                                                                                                                                                                                        |             |
| <b>M1</b>   | Integrate to obtain $\mathbf{r}$ . Powers increase by 1 in both components. Condone working with separated components. Condone missing brackets with $\mathbf{i-j}$ notation. M0 for <i>suvat</i> .                                                                                                                                                                                                                    |             |
| <b>A1</b>   | Correct integration. Condone missing constant of integration.                                                                                                                                                                                                                                                                                                                                                          |             |
| <b>DM1</b>  | <ul style="list-style-type: none"> <li>Dependent on the preceding M1.</li> <li>Must have a constant of integration before using <math>t = 3</math> (unless using definite integration)</li> <li>Must use <math>(-30\mathbf{i} - 45\mathbf{j})</math></li> <li>Must substitute <math>t = 3</math></li> </ul> Condone working with separated components.<br>DM0 if substitution of $t = 3$ occurs before finding $+ C$ . |             |

|             |                                                                                                                                                                                                                                                                                       |  |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
|             | $\left(t^3 + 6t^2 + 12t - 30\right)\mathbf{i} + \left(\frac{5}{3}t^3 + 5t^2 - 45\right)\mathbf{j} \quad C = (-30\mathbf{i} - 45\mathbf{j})$ $\left((t+2)^3 - 38\right)\mathbf{i} + \left(\frac{5}{3}t^3 + 5t^2 - 45\right)\mathbf{j} \quad K = (-38\mathbf{i} - 45\mathbf{j})$        |  |
| <b>A1</b>   | <p>Correct answer, accept column vector <math>\begin{pmatrix} 87 \\ 45 \end{pmatrix}</math></p> <p>A0 for poor notation in final answer eg <math>\begin{pmatrix} 87\mathbf{i} \\ 45\mathbf{j} \end{pmatrix}</math></p> <p>ISW if they continue and find <math> \mathbf{r} </math></p> |  |
| <b>1(b)</b> |                                                                                                                                                                                                                                                                                       |  |
| <b>M1</b>   | Differentiate to obtain <b>a</b> . Powers decrease by 1 in both components. Condone working with separated components and missing brackets with <b>i-j</b> notation. M0 for <i>suvat</i>                                                                                              |  |
| <b>A1</b>   | Correct differentiation                                                                                                                                                                                                                                                               |  |
| <b>M1</b>   | <p>Dependent on the preceding M1</p> <p>Use of Pythagoras seen or implied <math>\sqrt{30^2 + 40^2}</math></p>                                                                                                                                                                         |  |
| <b>A1</b>   | Correct only                                                                                                                                                                                                                                                                          |  |
| <b>1(c)</b> |                                                                                                                                                                                                                                                                                       |  |
| <b>M1</b>   | Correct method using the ratio of <b>i</b> and <b>j</b> components of <b>v</b> . Form an equation in <i>T</i> only. Accept working in <i>t</i> or <i>T</i> .                                                                                                                          |  |
| <b>A1</b>   | 0.86 or better. Condone <i>t</i> instead of <i>T</i> .                                                                                                                                                                                                                                |  |

| Question | Scheme                                                                                                                                                                                                                                                                                                       | Marks     |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 2        | Use of Impulse momentum equation                                                                                                                                                                                                                                                                             | M1        |
|          | $\mathbf{I} = 3(x\mathbf{i} + y\mathbf{j}) - 3 \times 5\mathbf{i}$ $= 3(x-5)\mathbf{i} + 3y\mathbf{j}$                                                                                                                                                                                                       | A1        |
|          | $ I ^2 = 9((x-5)^2 + y^2) = 9 \times 82 (=738)$                                                                                                                                                                                                                                                              | M1        |
|          | Equation for change in KE                                                                                                                                                                                                                                                                                    | M1        |
|          | $\frac{1}{2} \times 3(x^2 + y^2 - 25) = 138$ $(x^2 + y^2 - 25 = 92)$                                                                                                                                                                                                                                         | A1        |
|          | $(x-5)^2 + y^2 = 82$ $x^2 + y^2 = 117 \Rightarrow 10x = 60$                                                                                                                                                                                                                                                  | DM1       |
|          | $\mathbf{v} = 6\mathbf{i} + 9\mathbf{j} \text{ (ms}^{-1}\text{)}$                                                                                                                                                                                                                                            | A1        |
|          |                                                                                                                                                                                                                                                                                                              | (7)       |
| ALT      | Use of $I = \begin{pmatrix} 3\sqrt{82} \cos \theta \\ 3\sqrt{82} \sin \theta \end{pmatrix}$<br>$I = \begin{pmatrix} 3\sqrt{82} \cos \theta \\ 3\sqrt{82} \sin \theta \end{pmatrix} = 3 \begin{pmatrix} x \\ y \end{pmatrix} - 3 \begin{pmatrix} 5 \\ 0 \end{pmatrix}$                                        | M1 A1     |
|          | $ I ^2 = 9((x-5)^2 + y^2) = 9 \times 82$                                                                                                                                                                                                                                                                     | M1        |
|          | Equation for change in KE<br>$\frac{1}{2} \times 3(x^2 + y^2 - 25) = 138$                                                                                                                                                                                                                                    | M1 A1     |
|          | Leads to $\theta = 83.66\dots$<br>$x = 5 + 3\sqrt{82} \cos \theta = 6$<br>$y = 3\sqrt{82} \sin \theta = 9$<br>$\mathbf{v} = 6\mathbf{i} + 9\mathbf{j} \text{ (ms}^{-1}\text{)}$                                                                                                                              | DM1<br>A1 |
|          | Notes                                                                                                                                                                                                                                                                                                        |           |
| M1       | Find the difference in momenta. Dimensionally correct. Condone subtraction in wrong order. Must use both components. (Ignore $3\sqrt{82}$ if it appears on LHS)                                                                                                                                              |           |
| A1       | Correct unsimplified expression for difference in momentum. Condone subtraction the wrong way round.                                                                                                                                                                                                         |           |
| M1       | Correct use of Pythagoras with $3\sqrt{82}$ and both components of impulse. Ignore poor $\mathbf{i-j}$ notation, eg $\mathbf{i}^2$ for this mark, if recovered by correct subsequent working.                                                                                                                |           |
| M1       | Use change in KE to produce an equation in terms of $x$ and $y$ . Dimensionally correct, requires 2 KE terms of correct structure. Condone subtraction in wrong order. Ignore poor $\mathbf{i-j}$ notation eg $(x\mathbf{i})^2 + (y\mathbf{j})^2$ for this mark, if recovered by correct subsequent working. |           |

|            |                                                                                                     |  |
|------------|-----------------------------------------------------------------------------------------------------|--|
|            | M0 For use of velocity.                                                                             |  |
| <b>A1</b>  | Correct unsimplified equation<br>A0 for incorrect notation. A0 for subtraction the wrong way round. |  |
| <b>DM1</b> | Dependent on all preceding M marks. Solve for $x$ or $y$                                            |  |
| <b>A1</b>  | Correct velocity only. Accept column vector. ISW if continue to find speed.                         |  |

| Question    | Scheme                                                                                                                                                                                                                                                                                                                                                                                                                  | Marks |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| <b>3(a)</b> | Equation of motion for whole system.                                                                                                                                                                                                                                                                                                                                                                                    | M1    |
|             | $F - 640 - 1100g \sin \alpha = 1100a$                                                                                                                                                                                                                                                                                                                                                                                   | A1 A1 |
|             | Use of $P = Fv$ $F = \frac{15000}{12} (=1250)$                                                                                                                                                                                                                                                                                                                                                                          | M1    |
|             | $a = 0.16 (\text{ms}^{-2})$ or $a = 0.163 (\text{ms}^{-2})$                                                                                                                                                                                                                                                                                                                                                             | A1    |
|             |                                                                                                                                                                                                                                                                                                                                                                                                                         | (5)   |
| <b>3(b)</b> | Work-energy equation for the trailer.                                                                                                                                                                                                                                                                                                                                                                                   | M1    |
|             | $\frac{1}{2} \times 200 \times 14^2 = 240d + 200g \times \frac{1}{25} d$                                                                                                                                                                                                                                                                                                                                                | A1 A1 |
|             | $(AB =) 62 (\text{m})$ or $(AB =) 61.6 (\text{m})$                                                                                                                                                                                                                                                                                                                                                                      | A1    |
|             |                                                                                                                                                                                                                                                                                                                                                                                                                         | (4)   |
|             |                                                                                                                                                                                                                                                                                                                                                                                                                         | (9)   |
|             | Notes                                                                                                                                                                                                                                                                                                                                                                                                                   |       |
| <b>3(a)</b> |                                                                                                                                                                                                                                                                                                                                                                                                                         |       |
|             | Over-accuracy or under-accuracy is penalised max <b>once</b> per complete question. Penalise final A mark in the appropriate part.<br>Use of $g = 9.81$ or $10$ is penalised max <b>once</b> per complete question. Penalise final A mark in the appropriate part.<br>If both errors occur, could lose the final two A marks.                                                                                           |       |
| <b>M1</b>   | Equation of motion for whole system. All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion. May form two equations of motion (van and trailer) and combine to eliminate $T$ . Condone slip with zeroes for M mark. The forces on the LHS must be consistent with the mass in the ' $ma$ '.<br>Note that $\sin\left(\frac{1}{25}\right)$ is an accuracy error, <b>not</b> a method error. |       |
| <b>A1</b>   | Unsimplified equation in $F$ or $P$ with at most one error. Missing $g$ from both weight terms counts as 1 error.                                                                                                                                                                                                                                                                                                       |       |
| <b>A1</b>   | Correct unsimplified equation in $F$ or $P$                                                                                                                                                                                                                                                                                                                                                                             |       |
| <b>M1</b>   | Use of $P = Fv$ . Condone slip with zeroes for M mark.                                                                                                                                                                                                                                                                                                                                                                  |       |
| <b>A1</b>   | Correct answer, 2 sf or 3 sf.                                                                                                                                                                                                                                                                                                                                                                                           |       |
| <b>3(b)</b> |                                                                                                                                                                                                                                                                                                                                                                                                                         |       |
| <b>M1</b>   | Work-energy equation. Condone slip with zeroes for M mark. Dimensionally correct, all terms required and with correct structure: KE, GPE, WD. No repeats. Must use mass of trailer only. Condone sign errors and sin / cos confusion. M0 for <i>suvat</i> .<br>Note that $\sin\left(\frac{1}{25}\right)$ is an accuracy error, <b>not</b> a method error.                                                               |       |
| <b>A1</b>   | Unsimplified equation with at most one error.                                                                                                                                                                                                                                                                                                                                                                           |       |
| <b>A1</b>   | Correct unsimplified equation with mass replaced.                                                                                                                                                                                                                                                                                                                                                                       |       |
| <b>A1</b>   | Correct answer, 2 sf or 3 sf No need for $AB =$                                                                                                                                                                                                                                                                                                                                                                         |       |

| Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Scheme                                            |                                                         |                |                           |           | Marks |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|---------------------------------------------------------|----------------|---------------------------|-----------|-------|--|-----------------|---------------------|-----------|------|--------------------------------------------|--------------------------------------------|---------|------------------|------------------------------|------------------------------|-----|--|----------------|------------------|-----------|------|--------------------------------------------|--------------------------------------------|---------|------------------|---------------------------------------------------|---------------------------------------------------------|-----|
| 4(a)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                   |                                                         | Rectangle      | 2 x Triangle              | Trapezium |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Mass                                              |                                                         | $15a^2$        | $2 \times \frac{3}{2}a^2$ | $18a^2$   | B1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | From AD                                           |                                                         | $\frac{3}{2}a$ | $a$                       | $d$       | B1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Some examples of alternatives                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                   |                                                         |                |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| <div><div></div><div></div></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                   |                                                         |                |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| <div><table><tr><td></td><td>Large rectangle</td><td>2 removed triangles</td><td>Trapezium</td></tr><tr><td>Mass</td><td><math>21a^2</math></td><td><math>2 \times \frac{3a \times a}{2}</math></td><td><math>18a^2</math></td></tr><tr><td>Distance from AD</td><td><math>\frac{3a}{2}</math></td><td><math>\frac{2}{3} \times 3a = 2a</math></td><td><math>d</math></td></tr></table><table><tr><td></td><td>Large triangle</td><td>Removed triangle</td><td>Trapezium</td></tr><tr><td>Mass</td><td><math>\frac{147a^2}{4}</math></td><td><math>\frac{75a^2}{4}</math></td><td><math>18a^2</math></td></tr><tr><td>Distance from AD</td><td><math>\frac{1}{3} \times \frac{21a}{2} = \frac{7a}{2}</math></td><td><math>3a + \frac{1}{3} \times \frac{15a}{2} = \frac{11a}{2}</math></td><td><math>d</math></td></tr></table></div>                                           |                                                   |                                                         |                |                           |           |       |  | Large rectangle | 2 removed triangles | Trapezium | Mass | $21a^2$                                    | $2 \times \frac{3a \times a}{2}$           | $18a^2$ | Distance from AD | $\frac{3a}{2}$               | $\frac{2}{3} \times 3a = 2a$ | $d$ |  | Large triangle | Removed triangle | Trapezium | Mass | $\frac{147a^2}{4}$                         | $\frac{75a^2}{4}$                          | $18a^2$ | Distance from AD | $\frac{1}{3} \times \frac{21a}{2} = \frac{7a}{2}$ | $3a + \frac{1}{3} \times \frac{15a}{2} = \frac{11a}{2}$ | $d$ |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Large rectangle                                   | 2 removed triangles                                     | Trapezium      |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Mass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | $21a^2$                                           | $2 \times \frac{3a \times a}{2}$                        | $18a^2$        |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Distance from AD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | $\frac{3a}{2}$                                    | $\frac{2}{3} \times 3a = 2a$                            | $d$            |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Large triangle                                    | Removed triangle                                        | Trapezium      |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Mass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | $\frac{147a^2}{4}$                                | $\frac{75a^2}{4}$                                       | $18a^2$        |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Distance from AD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | $\frac{1}{3} \times \frac{21a}{2} = \frac{7a}{2}$ | $3a + \frac{1}{3} \times \frac{15a}{2} = \frac{11a}{2}$ | $d$            |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| <div><div></div><div></div></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                   |                                                         |                |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| <div><table><tr><td></td><td>Triangle ABC</td><td>Triangle ACD</td><td>Trapezium</td></tr><tr><td>Mass</td><td><math>\frac{5a \times 3a}{2} = \frac{15}{2}a^2</math></td><td><math>\frac{7a \times 3a}{2} = \frac{21}{2}a^2</math></td><td><math>18a^2</math></td></tr><tr><td>Distance from AD</td><td><math>\frac{2}{3} \times 3a = 2a</math></td><td><math>\frac{1}{3} \times 3a = a</math></td><td><math>d</math></td></tr></table><table><tr><td></td><td>Triangle ABD</td><td>Triangle ACD</td><td>Trapezium</td></tr><tr><td>Mass</td><td><math>\frac{7a \times 3a}{2} = \frac{21}{2}a^2</math></td><td><math>\frac{5a \times 3a}{2} = \frac{15}{2}a^2</math></td><td><math>18a^2</math></td></tr><tr><td>Distance from AD</td><td><math>\frac{1}{3} \times 3a = a</math></td><td><math>\frac{2}{3} \times 3a = 2a</math></td><td><math>d</math></td></tr></table></div> |                                                   |                                                         |                |                           |           |       |  | Triangle ABC    | Triangle ACD        | Trapezium | Mass | $\frac{5a \times 3a}{2} = \frac{15}{2}a^2$ | $\frac{7a \times 3a}{2} = \frac{21}{2}a^2$ | $18a^2$ | Distance from AD | $\frac{2}{3} \times 3a = 2a$ | $\frac{1}{3} \times 3a = a$  | $d$ |  | Triangle ABD   | Triangle ACD     | Trapezium | Mass | $\frac{7a \times 3a}{2} = \frac{21}{2}a^2$ | $\frac{5a \times 3a}{2} = \frac{15}{2}a^2$ | $18a^2$ | Distance from AD | $\frac{1}{3} \times 3a = a$                       | $\frac{2}{3} \times 3a = 2a$                            | $d$ |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Triangle ABC                                      | Triangle ACD                                            | Trapezium      |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Mass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | $\frac{5a \times 3a}{2} = \frac{15}{2}a^2$        | $\frac{7a \times 3a}{2} = \frac{21}{2}a^2$              | $18a^2$        |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Distance from AD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | $\frac{2}{3} \times 3a = 2a$                      | $\frac{1}{3} \times 3a = a$                             | $d$            |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Triangle ABD                                      | Triangle ACD                                            | Trapezium      |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Mass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | $\frac{7a \times 3a}{2} = \frac{21}{2}a^2$        | $\frac{5a \times 3a}{2} = \frac{15}{2}a^2$              | $18a^2$        |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Distance from AD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | $\frac{1}{3} \times 3a = a$                       | $\frac{2}{3} \times 3a = 2a$                            | $d$            |                           |           |       |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Moments about AD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                   |                                                         |                |                           |           | M1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| $15a^2 \times \frac{3}{2}a + 3a^2 \times a = 18a^2 d$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                   |                                                         |                |                           |           | A1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| $\frac{51}{2}a = 18d \Rightarrow d = \frac{17a}{12} *$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                   |                                                         |                |                           |           | A1*   |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                   |                                                         |                |                           |           | (5)   |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| 4(b)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | $\bar{x} = \frac{9}{2}a$                          |                                                         |                |                           |           | B1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Moments about PS or a parallel axis for Lamina                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                   |                                                         |                |                           |           | M1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| From PS: $27a^2 \bar{y} = 45a^2 \times 2.5a - 18a^2 \left( a + \frac{17}{12}a \right)$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                   |                                                         |                |                           |           | A1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| From AD: $27a^2 \bar{Y} = 45a^2 \times 1.5a - 18a^2 \left( \frac{17}{12}a \right)$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                   |                                                         |                |                           |           | A1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| $\bar{y} = \frac{69}{27}a = \frac{23}{9}a$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                   |                                                         |                |                           |           | A1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |
| Expression for relevant angle                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                   |                                                         |                |                           |           | M1    |  |                 |                     |           |      |                                            |                                            |         |                  |                              |                              |     |  |                |                  |           |      |                                            |                                            |         |                  |                                                   |                                                         |     |

|             |                                                                                                                                                                                                                                                |      |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
|             | $\tan \theta^\circ = \frac{\bar{y}}{"(9a/2)"} \quad \left( = \frac{46}{81} \right)$                                                                                                                                                            |      |
|             | $\theta = 29.6$                                                                                                                                                                                                                                | A1   |
|             |                                                                                                                                                                                                                                                | (7)  |
|             |                                                                                                                                                                                                                                                | (12) |
|             | <b>Notes</b>                                                                                                                                                                                                                                   |      |
| <b>4(a)</b> |                                                                                                                                                                                                                                                |      |
| <b>B1</b>   | Correct mass ratio.                                                                                                                                                                                                                            |      |
| <b>B1</b>   | Correct distances from $AD$ , for an appropriate division of $ABCD$<br>Distances may be measured from a parallel axis                                                                                                                          |      |
| <b>M1</b>   | Dimensionally consistent equation with all required terms. Accept working from a parallel axis. Accept an equation embedded in vector form.                                                                                                    |      |
| <b>A1</b>   | Correct unsimplified equation. Accept embedded in vector form.                                                                                                                                                                                 |      |
| <b>A1*</b>  | Obtain given answer from correct working. Working must include simplification or rearrangement (may be seen from table to equation). Answer must be extracted from vector form and have $d =$                                                  |      |
| <b>4(b)</b> |                                                                                                                                                                                                                                                |      |
| <b>B1</b>   | Distance of c of m of lamina from $PQ$ seen or implied. May not be seen until the trig ratio.                                                                                                                                                  |      |
| <b>M1</b>   | Complete method to find c of m of Lamina (remaining mass) from $PS$ or a parallel axis. Dimensionally consistent equation containing all required terms. If one distance is from $PS$ and the other is from $AD$ , treat as an accuracy error. |      |
| <b>A1</b>   | Unsimplified equation for $PS$ or their parallel axis, with at most one error                                                                                                                                                                  |      |
| <b>A1</b>   | Correct unsimplified equation for $PS$ or their parallel axis.                                                                                                                                                                                 |      |
| <b>A1</b>   | Correct distance of c of m from $PS$ , $2.6a$ or better                                                                                                                                                                                        |      |
| <b>M1</b>   | Correct use of trig for a relevant angle where $"(9a/2) "$ is their distance of the c of m of the lamina from $PQ$ and $\bar{y}$ is their <b>calculated</b> distance from $PS$ .<br>Allow with both $a$ 's or neither. Allow reciprocal.       |      |
| <b>A1</b>   | 30 or better (29.59229...) cao                                                                                                                                                                                                                 |      |

| Question    | Scheme                                                                                                                                                                                                                                                                                                                            | Marks       |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| <b>5(a)</b> | Horizontal motion to find expression for the distance                                                                                                                                                                                                                                                                             | M1          |
|             | $(XY =) u \cos \theta t$                                                                                                                                                                                                                                                                                                          | A1          |
|             | Method using vertical motion to find relevant equation in $t, u, g, \theta$ .<br>Eg<br><ul style="list-style-type: none"> <li>Using vertical distance = 0 to find expression for time.</li> <li>Find expression for time to max height and <math>\times 2</math></li> </ul>                                                       | M1          |
|             | Correct unsimplified equation in $t, u, g, \theta$ .<br>$u \sin \theta t - \frac{1}{2} g t^2 = 0$                                                                                                                                                                                                                                 | A1          |
|             | Solve to obtain the distance in terms of $u, g$ and $\theta$                                                                                                                                                                                                                                                                      | DM1         |
|             | $XY = u \cos \theta \times \frac{2u \sin \theta}{g} = \frac{u^2 \sin 2\theta}{g} *$                                                                                                                                                                                                                                               | A1*         |
|             |                                                                                                                                                                                                                                                                                                                                   | (6)         |
| <b>5(b)</b> | $CB = \frac{20^2 \times \sin 120^\circ}{g} - 12$                                                                                                                                                                                                                                                                                  | M1          |
|             | $CB = 23(\text{m})$ or $CB = 23.3(\text{m})$                                                                                                                                                                                                                                                                                      | A1          |
|             |                                                                                                                                                                                                                                                                                                                                   | (2)         |
| <b>5(c)</b> | Horizontal motion                                                                                                                                                                                                                                                                                                                 | M1          |
|             | $12 = 20 \cos 60^\circ t$                                                                                                                                                                                                                                                                                                         | A1          |
|             | Vertical motion<br>$y = 20 \sin 60^\circ \times 1.2 - \frac{1}{2} \times g \times 1.2^2 (-5)$                                                                                                                                                                                                                                     | M1          |
|             | Height above $D = 8.7(\text{m})$ or $8.73(\text{m})$                                                                                                                                                                                                                                                                              | A1          |
|             |                                                                                                                                                                                                                                                                                                                                   | (4)         |
|             |                                                                                                                                                                                                                                                                                                                                   | <b>(12)</b> |
|             | <b>Notes</b>                                                                                                                                                                                                                                                                                                                      |             |
|             | Over-accuracy or under-accuracy is penalised max <b>once</b> per complete question. Penalise final A mark in the appropriate part.<br>Use of $g = 9.81$ or $10$ is penalised max <b>once</b> per complete question. Penalise final A mark in the appropriate part.<br>If both errors occur they could lose the final two A marks. |             |
| <b>5(a)</b> |                                                                                                                                                                                                                                                                                                                                   |             |
| <b>M1</b>   | Use horizontal motion to find an expression for the horizontal distance.                                                                                                                                                                                                                                                          |             |
| <b>A1</b>   | Correct unsimplified equation.                                                                                                                                                                                                                                                                                                    |             |
| <b>M1</b>   | Method using vertical motion with relevant <i>suvat</i> to find an equation in $t, u, g, \theta$ (condone use of 9.8).<br>M0 if $t = \frac{2u \sin \theta}{g}$ or $t = \frac{u \sin \theta}{g}$ is quoted (ie if it appears without any evidence of method)                                                                       |             |
| <b>A1</b>   | Correct equation, (condone use of 9.8)<br>Eg<br><ul style="list-style-type: none"> <li><math>u \sin \theta t - \frac{1}{2} g t^2 = 0</math></li> </ul>                                                                                                                                                                            |             |

|             |                                                                                                                                                                      |  |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
|             | <ul style="list-style-type: none"> <li>• <math>-u \sin \theta = u \sin \theta - gt</math></li> <li>• <math>u \sin \theta - gt = 0</math> double the time.</li> </ul> |  |
| <b>DM1</b>  | Dependent on the preceding M marks. Solve to obtain the distance in terms of $u$ , $g$ and $\theta$ .                                                                |  |
| <b>A1*</b>  | Obtain given answer from correct working. Must recover $g$ if 9.8 is used. Must have $XY =$ at this stage.                                                           |  |
| <b>5(b)</b> |                                                                                                                                                                      |  |
| <b>M1</b>   | Complete method using result in (a), or using horizontal motion from first principles, to find the horizontal distance $CB$ .                                        |  |
| <b>A1</b>   | Correct answer, 2sf or 3sf                                                                                                                                           |  |
| <b>5(c)</b> |                                                                                                                                                                      |  |
| <b>M1</b>   | Complete method for horizontal motion to obtain an equation in $t$ . If $t=1.2$ o.e. is seen in earlier working, it must be used in (c) to earn the marks.           |  |
| <b>A1</b>   | Correct unsimplified equation ( $t = 1.2$ )                                                                                                                          |  |
| <b>M1</b>   | Method using <i>suvat</i> with vertical motion to obtain a relevant vertical distance. Height of pole not required.                                                  |  |
| <b>A1</b>   | Correct answer, 2 sf or 3 sf                                                                                                                                         |  |

| Question | Scheme                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Marks    |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 6(a)     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |          |
|          | Moments about A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | M1       |
|          | $5W \times 6a \cos \theta + W \times 12a \cos \theta = 9akW$ $\left( 30 \times \frac{12}{13} + 12 \times \frac{12}{13} = 9k \right)$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | A1<br>A1 |
|          | $\Rightarrow k = \frac{56}{13} *$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | A1*      |
|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | (4)      |
| 6(b)     | First relevant equation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | M1       |
|          | Correct unsimplified equation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | A1       |
|          | Relevant equations:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |          |
|          | <ul style="list-style-type: none"> <li>Vert: <math>R + kW \cos \theta = 6W \quad \left( R = \frac{342}{169} W \right)</math></li> <li>Horiz: <math>F = kW \sin \theta \quad \left( F = \frac{280}{169} W \right)</math></li> <li>// to AB: <math>F \cos \theta + R \sin \theta = 6W \sin \theta</math></li> <li>Perp to AB: <math>kW + R \cos \theta = 6W \cos \theta + F \sin \theta</math></li> <li>M(G): <math>R \cos \theta \times 6a + W \cos \theta \times 6a = F \sin \theta \times 6a + kW \times 3a</math></li> <li>M(C): <math>W \cos \theta \times 3a + R \cos \theta \times 9a = 5W \cos \theta \times 3a + F \sin \theta \times 9a</math></li> <li>M(B): <math>kW \times 3a + R \cos \theta \times 12a = 5W \cos \theta \times 6a + F \sin \theta \times 12a</math></li> </ul> |          |
|          | Second relevant equation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | M1       |
|          | Correct unsimplified equation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | A1       |
|          | Use of $F = \mu R$ to form an equation in $\mu$ only                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | DM1      |
|          | $\mu = \frac{280}{342} \left( = \frac{140}{171} \right) = 0.8187....$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | A1       |
|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | (6)      |
|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | (10)     |
|          | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |
|          | Note that an extra g in a resolution or moments equation is an accuracy error and not a method error.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |
| 6(a)     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |          |
| M1       | Complete method eg moments about A. All required terms present and no extra. Dimensionally correct, product of perpendicular force and distance (a and W present throughout). Condone sign errors and sin/cos confusion. Condone $R_c$ (or similar) instead of kW.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |          |
| A1       | Unsimplified equation with at most one error                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |          |
| A1       | Correct unsimplified equation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
| A1*      | Obtain given answer from correct working. Trig replaced and $R_c$ (or similar) replaced in terms of k. At least one line of working required                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |          |

|             |                                                                                                                                                                                                                                                                                                                       |  |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
|             | between the equation and the given answer. Do not accept embedded value for $k$ .                                                                                                                                                                                                                                     |  |
| <b>6(b)</b> |                                                                                                                                                                                                                                                                                                                       |  |
| <b>M1</b>   | First relevant equation. All required terms present and no extra. Dimensionally consistent. Condone sign errors and sin/cos confusion.                                                                                                                                                                                |  |
| <b>A1</b>   | Correct unsimplified equation. Trig does not need to be replaced. Condone $R_c$ (or similar) instead of $kW$ .                                                                                                                                                                                                        |  |
| <b>M1</b>   | Second relevant equation. To be relevant it must be possible to use with the first equation to find $\mu$ (at least one equation must be a horizontal, vertical, parallel or perpendicular resolution). All required terms present and no extra. Dimensionally consistent. Condone sign errors and sin/cos confusion. |  |
| <b>A1</b>   | Correct unsimplified equation. Trig does not need to be replaced. Condone $R_c$ (or similar) instead of $kW$ .                                                                                                                                                                                                        |  |
| <b>DM1</b>  | Depending on the two previous M marks. Use of $F = \mu R$ to reach $\mu = \dots$                                                                                                                                                                                                                                      |  |
| <b>A1</b>   | $\frac{280}{342} \left( = \frac{140}{171} \right) = 0.8187\dots$ Accept 0.82 or better                                                                                                                                                                                                                                |  |

| Question | Scheme                                                                                                                                                                                                                                                                                                                                                                                                | Marks |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
|          |                                                                                                                                                                                                                                                                                                                                                                                                       |       |
| 7(a)     | CLM                                                                                                                                                                                                                                                                                                                                                                                                   | M1    |
|          | $10mu - 6mu = 5mx + 2my$<br>$(4u = 5x + 2y)$                                                                                                                                                                                                                                                                                                                                                          | A1    |
|          | Impact law                                                                                                                                                                                                                                                                                                                                                                                            | M1    |
|          | $y - x = 5ue$                                                                                                                                                                                                                                                                                                                                                                                         | A1    |
|          | $4u = 5x + 2x + 10ue (= 7x + 10ue)$                                                                                                                                                                                                                                                                                                                                                                   | DM1   |
|          | $(x > 0 \Rightarrow) 10ue < 4u$                                                                                                                                                                                                                                                                                                                                                                       | DM1   |
|          | $\Rightarrow 0, e < \frac{2}{5}$ o.e.                                                                                                                                                                                                                                                                                                                                                                 | A1    |
|          |                                                                                                                                                                                                                                                                                                                                                                                                       | (7)   |
| 7(b)     | Impulse momentum equation                                                                                                                                                                                                                                                                                                                                                                             | M1    |
|          | $\frac{60}{7}mu = 2m(3u - (-y))$<br>or<br>$-\frac{60}{7}mu = 5m(x - 2u)$                                                                                                                                                                                                                                                                                                                              | A1    |
|          | Solve to find a correct expression for either $x$ or $y$<br>$\left( y = \frac{9}{7}u, x = \frac{2}{7}u \text{ but may not be seen explicitly} \right)$                                                                                                                                                                                                                                                | DM1   |
|          | <div>Use both impulse equations and impact law with their <math>x</math> and <math>y</math> to form an equation in <math>e</math> (and <math>u</math>).<br/> <math>5ue = \frac{9}{7}u - \frac{2}{7}u</math></div> <div>Using CLM and impact law from part (a) to form an equation in <math>e</math> (and <math>u</math>).<br/> For example<br/> <math>\frac{2u}{7} = \frac{4u - 10eu}{7}</math></div> | M1    |
|          | $e = \frac{1}{5u} \left( \frac{9}{7}u - \frac{2}{7}u \right) = \frac{1}{5} *$                                                                                                                                                                                                                                                                                                                         | A1*   |
|          |                                                                                                                                                                                                                                                                                                                                                                                                       | (5)   |
| 7(c)     |                                                                                                                                                                                                                                                                                                                                                                                                       |       |
|          | Speed of $Q = \frac{1}{3} \times \frac{9}{7}u \left( = \frac{3}{7}u \right)$                                                                                                                                                                                                                                                                                                                          | B1ft  |
|          | Magnitude of impulse = $\frac{1}{7} \times \frac{60}{7}mu$                                                                                                                                                                                                                                                                                                                                            | M1    |
|          | $= \frac{60}{49}mu$                                                                                                                                                                                                                                                                                                                                                                                   | A1    |

|             |                                                                                                                                                                                                                                                                       |      |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
|             |                                                                                                                                                                                                                                                                       | (3)  |
|             |                                                                                                                                                                                                                                                                       | (15) |
|             | <b>Notes</b>                                                                                                                                                                                                                                                          |      |
| <b>7(a)</b> |                                                                                                                                                                                                                                                                       |      |
| <b>M1</b>   | Form CLM equation. All terms required. Mass and velocity correctly paired. Dimensionally consistent, condone consistent additional $g$ in each term. Condone sign errors.                                                                                             |      |
| <b>A1</b>   | Correct equation or equivalent. Condone consistent additional $g$ in each term. Condone $\pm y$ .                                                                                                                                                                     |      |
| <b>M1</b>   | Use Impact Law. Dimensionally correct. Used the right way round (separation and approach must not be interchanged). Condone sign errors.                                                                                                                              |      |
| <b>A1</b>   | Correct equation or equivalent. Directions of $P$ and $Q$ after impact must be consistent with CLM.                                                                                                                                                                   |      |
| <b>DM1</b>  | Dependent on the preceding M marks. Eliminate velocity of $Q$ to form an equation in $x$ , $e$ and $u$ only.<br>$\left( x = \frac{4u - 10eu}{7} \right)$                                                                                                              |      |
| <b>DM1</b>  | Dependent on all preceding M marks. May be implied by $e < 0.4$<br>Use direction of $P$ to form an inequality in $e$ (and $u$ ). Use correct inequality for their diagram: if they had $P$ changing direction should now be using $x < 0$                             |      |
| <b>A1</b>   | Both ends required $0 \leq e < 0.4$ but condone $0 < e < 0.4$                                                                                                                                                                                                         |      |
| <b>7(b)</b> |                                                                                                                                                                                                                                                                       |      |
| <b>M1</b>   | Impulse-momentum equation. Dimensionally correct, using the correct mass and velocity pair for a single particle. Must be subtracting momenta but allow incorrect order. May use working in terms of $e$ from (a) $x = \frac{4u - 10eu}{7}$ $y = \frac{25eu + 4u}{7}$ |      |
| <b>A1</b>   | At least one correct unsimplified equation.                                                                                                                                                                                                                           |      |
| <b>DM1</b>  | Solve impulse-momentum equation to find either $y = \frac{9}{7}u$ or<br>$x = \frac{2}{7}u$                                                                                                                                                                            |      |
| <b>M1</b>   | Complete method to form an equation in $e$ (and $u$ ) only with the usual rules for CLM and Impact Law.                                                                                                                                                               |      |
| <b>A1*</b>  | Obtain given answer from complete and correct working.<br>A0 for 0.2                                                                                                                                                                                                  |      |
| <b>7(c)</b> |                                                                                                                                                                                                                                                                       |      |
| <b>B1</b>   | Follow $\frac{1}{3} \times$ their $y$ from part (b). If $y$ is given in terms of $e$ then $e = \frac{1}{5}$ must be substituted at some point. Seen or implied. May appear on diagram. Accept $\pm$ .                                                                 |      |

|           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| <b>M1</b> | <p>Complete method using (a) and (b) and working from first principles to find the impulse in the second collision between <math>P</math> and <math>Q</math>.<br/>Must see:</p> <ul style="list-style-type: none"> <li>Usual rules for CLM and Impact Law to <b>find</b> <math>V_p</math> or <math>V_q</math> after second collision.<br/>CLM<br/> <math display="block">\frac{10mu}{7} - \frac{6mu}{7} = 5mV_p + 2mV_q</math> Impact Law<br/> <math display="block">\frac{1}{5} \times \left( \frac{2u}{7} + \frac{3u}{7} \right) = V_q - V_p</math></li> <li><b>Then</b> use of Impulse – momentum equation with usual rules to find magnitude of impulse.<br/>Impulse – momentum<br/> Either <math>I = 2m \left( \frac{9u}{49} - -\frac{3u}{7} \right)</math> or <math>I = 5m \left( \frac{2u}{49} - \frac{2u}{7} \right)</math></li> </ul> |  |
| <b>A1</b> | 1.2mu or better (1.2244897...)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |  |