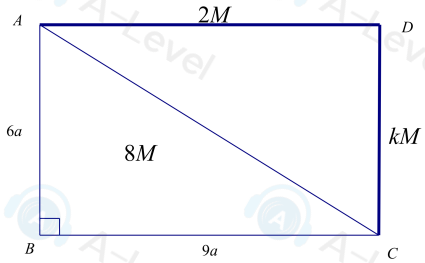
| Question Number | Scheme | Marks |
|---|---|---|
| **7a** |  <br>Moments about $AB$: $(10+k)M\bar{x} = 8M\times 3a + 2M\times\frac{9a}{2} + kM\times 9a$<br>$(10+k)\bar{x} = 24a+9a+9ka = (33+9k)a$<br>$\bar{x} = \left(\frac{33+9k}{10+k}\right)a$ ***Given Answer*** | M1A2<br><br>A1<br>**(4)** |
| **7b** | Moments about $AD$: $(10+k)M\bar{y} = 8M\times 4a + kM\times 3a$<br>$\bar{y} = \left(\frac{32+3k}{10+k}\right)a$<br>$AC$ vertical: $\frac{3}{2} = \frac{\bar{x}}{\bar{y}} = \frac{33+9k}{32+3k}$ follow their $\bar{y}$<br>$(32+3k = 2(11+3k))$<br>$k = \frac{10}{3}$ | M1A2<br>A1<br>M1A1ft<br><br>A1 |
| **7balt** | Moments about $BC$: $(10+k)M\bar{y} = 8M\times 2a + kM\times 3a + 2M\times 6a$<br>$\bar{y} = \left(\frac{28+3k}{10+k}\right)a$<br>$AC$ vertical: EITHER $\frac{3}{2} = \frac{\bar{x}}{6a-\bar{y}}\left(=\frac{33+9k}{32+3k}\right)$ follow their $\bar{y}$<br>$(32+3k = 2(11+3k))$<br>$k = \frac{10}{3}$<br>OR $\frac{2}{3} = \frac{\bar{y}}{9a-\bar{x}}\left(=\frac{28+3k}{57}\right)$ follow their $\bar{y}$<br>$(114 = 84+9k)$<br>$k = \frac{10}{3}$ | (M1A2)<br>(A1)<br><br>(M1A1)<br><br>(A1)<br>(M1A1)<br><br>(A1)<br>**(7)**<br>**Total 11** |

| Notes | |
|---|---|
| **a** | |
| M1 | Dimensionally correct moments equation about a *AB* (or parallel). Must have 4 terms. *M* must be included in all terms or none. If numerical distances are clearly included in each term, treat consistent omission of *a* as (a single) accuracy error. Might only be seen in a vector equation. |
| A1A1 | -1 each error. Allow correct equation about any line parallel to *AB*. |
| A1 | Given answer reached convincingly. |
| **b** | |
| M1 | Dimensionally correct moments equation about a *AD* (or parallel). Must have 4 terms. *M* must be included in all terms or none. If numerical distances are clearly included in each term, treat consistent omission of *a* as an accuracy error. Might be seen in part (a), but must be used in (b) to score marks. |
| A1A1 | -1 each error. Allow correct equation about any line parallel to *AD*. |
| A1 | Correct $\bar{y}$. Could be from *BC*. |
| M1 | Use their CoM and the fact that *AC* is vertical to form equation in *k* only. Follow through their $\bar{y}$, but must be considering appropriate distances. Condone = 2/3 for M1. |
| A1ft | Correct equation. Follow through their $\bar{y}$ |
| A1 cao | $k = \frac{10}{3}$ o.e. If no fraction seen, accept 3.33 or better. |

| | | | |
|---|---|---|---|
| 2a | NB If they use $a = 0$ then max score is 1/7 (3rd M1 only) | | |
| | Equation of motion for van + trailer: | M1 | First equation: Dimensionally correct. Need all terms. In $F$ or $P$. Condone sign errors. |
| | $F-(500+200)=(900+300)a$ | A1 | Correct unsimplified equation |
| | Equation of motion for the trailer | M1 | Second equation: Dimensionally correct. Need all terms. In $F$ or $P$. Condone sign errors. Correct mass |
| | $T-200=300a$ | A1 | Correct unsimplified equation. Follow their $a$. |
| | Equation of motion for van<br>$F-T-500=900a$ | | There are 3 possible equations. They need 2 of them. M1A1 for each correct unsimplified equation. |
| | $F=\frac{18000}{12}(=1500)$ | M1 | Use of $P=Fv$ Need to have substituted relevant values<br>Condone use of 18 in place of 18000 (or incorrect number of zeros) |
| | Solve for $T$ | DM1 | Dependent on previous 3 M marks |
| | $T=400$ | A1 | Correct only |
| | | | NB: Inclusion of $g$ should be marked as an accuracy error |
| | | **[7]** | |
| | | | |
| 2b | Equation of motion for van + trailer | M1 | Dimensionally correct. Need all terms. Condone sign errors.<br>Condone sine / cosine confusion<br>Alt: Obtains separate equations for van and trailer and eliminates $T$ |
| | $F-(200+500)-(300+900)g\sin\alpha=0$<br>$\left(\frac{18000}{v}=700+\frac{1200g}{15}\right)$ | A1<br><br><br><br>A1 | Unsimplified equation in $F$ or $v$ with at most one error. Consistent trig confusion is one error. Consistent sign error is one error. Missing $g$ is one error.<br>Correct unsimplified equation in $v$<br>Allow with trig value not substituted |
| | $v=12$ or $v=12.1$ | A1 | 2 sf or 3 sf |
| | | **[4]** | |
| | | **(11)** | |
| | | | |

| Question | Scheme | Mark | Notes |
|---|---|---|---|
| **1** | Accept column vectors throughout this question | | |
| 1a | Differentiate **r** (both components) | M1 | In each component at least one power going down by 1 |
| | $\mathbf{v}=\left(4t^3-16t\right)\mathbf{i}+\left(12t-3\sqrt{t}\right)\mathbf{j}$ | A1 | Accept as two separate components |
| | Equate **i** component of **v** to zero and solve for $t$ | DM1 | Dependent on the first M1.<br>Must start with a component of the vector for **v**<br>Can have more than one value at this stage. |
| | Obtain $\left(24-3\sqrt{2}\right)\mathbf{j}\ \left(\text{m s}^{-1}\right)$ | A1 | Accept $20\mathbf{j}\left(\text{m s}^{-1}\right)$ or better. (19.757359…)<br>Correct answer only<br>Answer must be a vector |
| | | **[4]** | |
| 1b | Differentiate **v** (both components) | M1 | For differentiating their **v**, even if the method for obtaining it was incorrect. Their **v** must be a vector.<br>In each component at least one power going down by 1 |
| | Obtain<br>$\mathbf{a}=\left(12t^2-16\right)\mathbf{i}+\left(12-\frac{3}{2}t^{-\frac{1}{2}}\right)\mathbf{j}$ | A1 | Any equivalent form for acceleration |
| | Obtain $176\mathbf{i}+\frac{45}{4}\mathbf{j}\left(\text{m s}^{-2}\right)$ | A1 | Accept $180\mathbf{i}+11\mathbf{j}\left(\text{m s}^{-2}\right)$ or better<br>ISW |
| | | **[3]** | |
| | | **(7)** | |

| Q | Scheme | Marks | Notes |
|---|---|---|---|
| **3(a)** | <table><tr><td>Large disc</td><td>Small disc</td><td>Template</td></tr><tr><td>$\pi R^2$</td><td>$\pi r^2$</td><td>$\pi R^2 - \pi r^2$</td></tr><tr><td>0</td><td>$R-r$</td><td>$\pm kr$</td></tr></table> | B1 | correct area ratios and distances seen or implied<br>Allow + *kr* or -*kr* |
| | Moments about axis through $X$ | M1 | Or moments about a parallel axis.<br>Need all terms but condone sign errors<br>Do not need to see the zero term<br>Dimensionally consistent<br>Could be part of a vector equation |
| | $(0\times\pi R^2)-\pi r^2\times(R-r)=\left(\pi R^2-\pi r^2\right)\times(-kr)$<br>Moments about the left-hand end of the diameter through $X$ and $Y$ gives:<br>$\pi R^2.R-\pi r^2\left(2R-r\right)=\pi\left(R^2-r^2\right)\left(R-kr\right)$ | A1 | Correct unsimplified equation<br>Do not need to see the zero term<br>Must be using – *kr* (unless they have changed the sign on the left-hand side) |
| | $r=\dfrac{k}{1-k}R$ * | A1* | Obtain **given answer** from correct working e.g. via $\dfrac{r}{R+r}=k$ |
| | | | If they use $\bar{x}$ in place of $\pm kr$ and never substitute $\pm kr$ they can score B0M1A0A0 |
| | | (4) | |
| **3(b)** | $0<\dfrac{k}{1-k}R<R$ | M1 | use of correct inequality |
| | $(0<)k<(1-k)\Rightarrow(0<)k<\dfrac{1}{2}$ | A1 | Correct only<br>Only need the right-hand value.<br>A0 with an incorrect left hand value |
| | | (2) | |
| **3(c)** | $k=\dfrac{4}{9}\Rightarrow r=\dfrac{4}{5}R$ | B1 | Seen or implied (this mark could be implied by the correct expression for tan$\alpha$ in terms of *k*) |
| | $\tan\alpha=\dfrac{R}{kr}\left(=\dfrac{R}{\frac{4}{9}\times\frac{4}{5}R}=\dfrac{45}{16}\right)$<br>$\left(\tan\alpha=\dfrac{1-k}{k^2}\right)$ | M1 | Correct use of trig in a correct triangle<br>Available for finding 90 - $\alpha$ |
| | $\alpha=70^{\circ}$ | A1 | or better (70.426…)<br>Accept 109.6, 250.4 and 289.6 |
| | | (3) | |

| Question Number | Scheme | Marks |
|---|---|---|
| **1** | Impulse-momentum principle: $(7\mathbf{i}-5\mathbf{j})=4\mathbf{v}-4(2\mathbf{i}+3\mathbf{j})$ | M1A1 |
| | $\left(\mathbf{v}=\frac{15}{4}\mathbf{i}+\frac{7}{4}\mathbf{j}\right)$ | A1 |
| | $\lvert\mathbf{v}\rvert=\frac{1}{4}\sqrt{15^2+7^2}$ | M1 |
| | $=\frac{1}{4}\sqrt{274}=4.1\,(\text{m s}^{-1})$ (or better) | A1 cso |
| | | (5) |
| | | [5] |
| | **Notes** | |
| | First M1 for use of Impulse-Momentum principle, dim correct, correct no. of terms and must be a *difference* of momenta.<br>First A1 for a correct equation<br>Second A1 for correct velocity vector<br>Second M1 for attempt to find magnitude of their **v**<br>Third A1 cso for an exact answer or 4.1 or better | |
| **2a** | Use of $P = Fv$ : $280 = F \times 2$ oe | M1 |
| | Equation of motion: $F-75g\sin\theta=R$ | M1 A1 |
| | $140-75\times9.8\times\frac{1}{21}=R$ | |
| | $R=105$ (or 110) | A1 |
| | | (4) |
| | **Notes** | |
| | First M1 for $280 = F \times 2$ oe<br>Second M1 for resolving parallel to the plane with $a = 0$ with usual rules | |
| | First A1 for a correct equation as shown | |
| | Second A1 for 105 or 110 | |
| **2b** | Equation of motion: $75g\sin\theta+\frac{280}{3.5}-60=75a$ or $-75a$ | M1A2 |
| | $a=0.73$ $(\text{m s}^{-2})$ (0.733) or – 0.73 (- 0.733) | A1 |
| | | (4) |
| | | [8] |
| | **Notes** | |
| | First M1 for resolving parallel to the plane with $a \neq 0$ with usual rules<br>First A1and Second A1 for a correct equation. Deduct 1 mark for each incorrect term. (A1A0 or A0A0) (Use of 280/2 is an A error)<br>Third A1 for 0.73 or 0.733 (allow negative answers) | |
| | | |
| **3a** | Integrate: $v=\int(4t-8)\,\mathrm{d}t=2t^2-8t\,(+C)$ | M1 |

| Question Number | Scheme | Marks | |
|---|---|---|---|
| **3a** | Use $\mathbf{v}=\lambda(\mathbf{i}+\mathbf{j})$: $6T^2+6T=3T^2+24$ | M1 | Form an equation in $t$, $T$ or $\lambda$<br>$\lambda^2-108\lambda+2592=0$ |
| | Solve for $T$ $3T^2+6T-24=0$, | M1 | Simplify to quadratic in $t$, $T$ or $\lambda$ and solve. |
| | $(T+4)(T-2)=0$, $T=2$ | A1 | $T=2$ only |
| | | (3) | |
| | If they score M1 and then state $T=2$ allow 3/3 | | |
| | If they guess $T=2$ and show that it works then allow 3/3. | | |
| | If all we see is $T=2$ with no equation then 0/3 for (a) but full marks are available for (b) and (c). | | |
| **3b** | Differentiate: $\mathbf{a}=(12t+6)\mathbf{i}+6t\mathbf{j}$ | M1 | Majority of powers going down<br>Need to be considering both components |
| | | A1 | Correct in $t$ or $T$ |
| | $=30\mathbf{i}+12\mathbf{j}$ (m s$^{-2}$) | A1 | CAO |
| | | (3) | |
| **3c** | Integrate : $\mathbf{r}=(2t^3+3t^2(+A))\mathbf{i}+(t^3+24t(+B))\mathbf{j}$ | M1 | Clear evidence of integration.<br>Need to be considering both components<br>Do not need to see the constant(s) |
| | | A2 | -1 each error |
| | If the integration is seen in part (a) it scores no marks at that stage, but if the result is used in part (c) then the M1A2 is available in part (c) | | |
| | $\boldsymbol{OA}=28\mathbf{i}+56\mathbf{j}$ Use their $T$ | | |
| | Distance $=28\sqrt{5}=62.6$ (m) | DM1 | Dependent on previous M1<br>Use of Pythagoras on their $\boldsymbol{OA}$ |
| | | A1 | 63 or better , $\sqrt{3920}$ |
| | | (5) | |
| | NB: Incorrect $T$ can score 2/3 in (b) and 4/5 in (c) | | |
| | | | |
| | | [11] | |
| | . | | |
| | | | |

| Q | Scheme | Marks | Notes |
|---|---|---|---|
| **6(a)** | $F = \dfrac{1000P}{10}$ | M1 | Use of $P = Fv$ |
| | Equation of motion | M1 | All terms required. Dimensionally correct. Accept separate equations for the car and the trailer. |
| | $F - 300g\sin\alpha - 800g\sin\alpha - 200 - 600 = 1100\times 0.5$ | A1 | Unsimplified equation(s) with at most one error |
| | | A1 | Correct unsimplified equation in $F$ (or $P$) |
| | $P = 21.2$ | A1 | Accept 21. Max. 3 sf |
| | | **(5)** | |
| | | | |
| **6(b)** | Work-energy equation for the trailer | M1 | The Q requires work-energy. Equation for the trailer, with all terms dimensionally correct. Condone sign errors |
| | $200d = \dfrac{1}{2}.300.12^2 - 300dg\sin\alpha$ | A1 | Unsimplified equation with at most one error |
| | | A1 | Correct unsimplified equation |
| | Solve for $d$ | DM1 | Dependent on the previous M1 |
| | $d = 52.7\ (\text{m})$ or $53\ (\text{m})$ | A1 | Max 3 sf |
| | | **(5)** | |
| | | **[10]** | |
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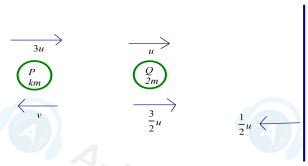
|---|---|---|---|
| 4a | If the division of the shape involves non-standard shapes (e.g. a trapezium) the centres of mass must be quoted correctly or a correct method used to find the position to score any marks. | | |
| | <table><tr><td>rectangle</td><td>-triangle</td><td>+triangle</td></tr><tr><td>$20a^2$</td><td>$-\frac{9}{2}a^2$</td><td>$\frac{9}{2}a^2$</td></tr><tr><td>$2a$</td><td>$3a$</td><td>$2a$</td></tr></table> or <table><tr><td>rectangle</td><td>rectangle</td><td>Double triangle</td></tr><tr><td>$3a^2$</td><td>$8a^2$</td><td>$9a^2$</td></tr><tr><td>$\frac{1}{2}a$</td><td>$2a$</td><td>$2a$</td></tr></table> or <table><tr><td>rectangle</td><td>trapezium</td><td>triangle</td></tr><tr><td>$5a^2$</td><td>$\frac{21}{2}a^2$</td><td>$\frac{9}{2}a^2$</td></tr><tr><td>$\frac{1}{2}a$</td><td>$\frac{48}{21}a$</td><td>$2a$</td></tr></table> | B1<br><br>B1 | Correct mass ratios for a correct division of the folded template and correct total of $20a^2$<br>Correct distances from $AD$ seen or implied.<br>B0B1 is possible if they have incorrect masses but a full set of correct distances. e.g. if they use the second alternative but have not doubled the triangle. Or they might have a correct split with an error in one of the areas or an incorrect (or missing) total<br><br>or equivalent |
| | Moments about $AD$ or a parallel axis. | M1 | Dimensionally consistent.<br>All terms for a correct division of $L$ and no extras.<br>Accept as part of a vector equation |
| | $40a^3-\frac{27}{2}a^3+9a^3=20a^2d$<br>or $\frac{3}{2}a^3+16a^3+18a^3=20a^2d$<br>or $\frac{2}{2}a^3+\frac{48}{2}a^3+9a^3=20a^2d$ | A1 | Correct unsimplified equation for their axis. Allow for correct component in a vector equation. |
| | $d=\frac{71}{40}a$ * | A1* | Obtain given answer from correct working. Need at least one line of working to **collect like terms** e.g. $20d=\frac{71}{2}a$ Final answer must be as printed i.e. $d=\ldots$. |
| | | **[5]** | |
| 4b | Moments about $S$ | M1 | A complete method to get an equation in $W$ and $F$ only.<br>Need all terms and no extras.<br>Dimensionally consistent. |
| | NB If they start by finding the centre of mass for the system they do not score marks until they form the moments equation.<br>If they are clearly using moments about $A$ (e.g. $d$ and $4a$ used as distances in their equation) this is M0 unless they include the reaction at $S$ and resolve to form the required equation.<br>If they say they are using moments about $S$ and have just one incorrect distance allow M1A1A0A0 | | |
| | $4W\times\frac{31}{40}a+W\times3a=F\times5a$<br>or $(4W+W)(2.22a-a)=5aF$ | A1<br><br>A1 | Unsimplified equation with at most one error<br>Correct unsimplified equation |
| | $F=\frac{61}{50}W$ | A1 | Accept $1.22W$ or $1.2W$ |
| | | **[4]** | |
| | | **(9)** | |

edexcel

# October 2019
# Mechanics 2 - WME02
# Mark Scheme - Final

| Q | Scheme | Marks | Notes |
|---|---|---|---|
| **1** | Moments about $y$-axis | M1 | Or a parallel axis. Require all terms and dimensionally correct. Condone sign errors $3m\bar{x}$ or $3\bar{x}$ is a method error |
| | $(k+4)m\bar{x} = 2m+12m+km$ | A1 | Or equivalent |
| | Moments about $x$-axis | M1 | Or a parallel axis. Require all terms and dimensionally correct. Condone sign errors $3m\bar{y}$ or $3\bar{y}$ is a method error |
| | $(k+4)m\bar{y} = m+9m+5km$ | A1 | Or equivalent |
| | | | Allow the first 4 marks for a combined equation in vector format |
| | Use of $\bar{y} = 2\bar{x}$ to form equation in $k$ | M1 | |
| | | | Allow the first 5 marks if they go straight to an equation equating the right hand sides e.g. $m+9m+5km = 2(2m+12m+km)$ with no incorrect statement about the total mass seen |
| | $10+5k = 2(14+k) \Rightarrow k = 6$ | A1 | With no errors seen |
| | | **(6)** | |
| | | **[6]** | |
| **2** | Use of $F = \dfrac{16000}{U}$ | M1 | $\dfrac{16}{U}$ scores M0 |
| | Equation of motion. | M1 | All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion. |
| | $F - 30U - 750g\sin\theta = 0$ | A1 | Correct unsimplified equation in $F$ or their $F$ |
| | $\Rightarrow \dfrac{16000}{U} - 30U - 490 = 0$<br>$30U^2 + 490U - 16000 = 0$ | DM1 | Form and solve a quadratic equation in $U$<br>Horizontal form seen or implied.<br>Dependent on the two preceding M marks<br>Need to see working if solving an incorrect quadratic or obtain an incorrect answer. |
| | $U = 16.3$ or $U = 16$ only | A1 | Max 3 sf |
| | | **(5)** | |
| | | **[5]** | |

| Q | Scheme | Marks | Notes |
|---|---|---|---|
| |  | | |
| **7a** | Impact law: $\frac{3}{2}u+v=e(3u-u)\left(=2eu\right)$ | M1 | Used the right way round |
| | $\left(v=2eu-\frac{3}{2}u\right)$ | A1 | Correct unsimplified equation |
| | $v>0 \Rightarrow 2e>\frac{3}{2}$ | M1 | Form and solve correct inequality for their $v$ |
| | $\left(1\geq\right)e>\frac{3}{4}$ | A1 | Accept $1>e>\frac{3}{4}$ and $e>\frac{3}{4}$ |
| | | (4) | |
| **7a alt** | Impact law: $\frac{3}{2}u+v=e(3u-u)\left(=2eu\right)$ | M1 | Used the right way round |
| | $\left(v=2eu-\frac{3}{2}u\right)$ | A1 | Correct unsimplified equation |
| | CLM $\Rightarrow v=\frac{u}{k}(1-3k)>0\Rightarrow k<\frac{1}{3}$ | M1 | Use CLM to form inequality in k and substitute into impact equation |
| | $e=\frac{1}{2k}-\frac{3}{4}>\frac{3}{2}-\frac{3}{4}\Rightarrow\frac{3}{4}<e\left(\leq1\right)$ | A1 | |
| | | (4) | |
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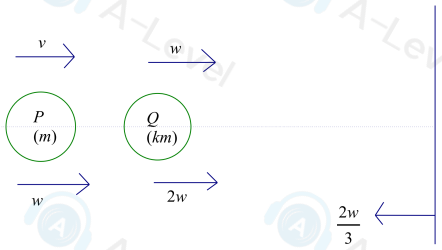
| Q | Scheme | Marks | Notes |
|---|---|---|---|
| **7b** | $e=\frac{7}{8} \Rightarrow v=\frac{7}{4}u-\frac{3}{2}u=\frac{1}{4}u$ | B1 | |
| | CLM : $3kmu+2mu=2m\times\frac{3}{2}u-kmv \qquad \left(3ku=u-kv\right)$ | M1 | Need all terms and dimensionally consistent.<br>If only seen in (a) it must be used in (b) to score. |
| | $\left(3k+2=3-\frac{1}{4}k\right)$ | A1 | Correct unsimplified equation |
| | $k=\frac{4}{13}$ | A1 | |
| | KE lost: $\frac{1}{2}\times\frac{4}{13}m\left(9u^2-\frac{u^2}{16}\right)$ | M1 | Accept in terms of k e.g. $\frac{1}{2}km\left(9u^2-\frac{1}{16}u^2\right)$ |
| | $=\frac{2}{13}m\times\frac{143}{16}u^2=\frac{11}{8}mu^2$ ***Given answer*** | A1 | Obtain given answer from correct working<br>Fully correct substitution seen |
| | | (6) | |
| | | | |
| **7c** | Time for $Q$ to reach wall: $\frac{2d}{3u}$ | B1 | |
| | Speed of $Q$ after collision with wall: $\frac{1}{3}\times\frac{3}{2}u=\frac{1}{2}u$ | B1 | |
| | $P$ has moved $\frac{u}{4}\times\frac{2d}{3u}=\frac{d}{6}$ | B1 | |
| | Gap $d+\frac{d}{6}=\frac{7d}{6}$ closing at $\frac{1}{2}u-\frac{1}{4}u=\frac{1}{4}u$ | M1 | |
| | takes $\frac{7d}{6}\div\frac{u}{4}=\frac{14d}{3u}$ | M1 | Terms dimensionally correct |
| | Total time $\frac{14d}{3u}+\frac{2d}{3u}=\frac{16d}{3u}$ | A1 | |
| | | (6) | |

| Q | Scheme | Marks | Notes |
|---|---|---|---|
| **7c alt** | Time for $Q$ to reach wall: $\frac{2d}{3u}$ | B1 | |
| | Speed of $Q$ after collision with wall: $\frac{1}{3}\times\frac{3}{2}u=\frac{1}{2}u$ | B1 | |
| | Total time for $Q$: $\frac{2d}{3u}+\frac{2x}{u}$ | B1 | |
| | Equal times: $\frac{2d}{3u}+\frac{2x}{u}=\frac{4(x-d)}{u}$ | M1 | Terms dimensionally correct. Condone a sign error |
| | Solve for $x$: $2d+6x=12x-12d,\quad x=\frac{7d}{3}$ | M1 | |
| | Time $=\frac{4}{u}\times\frac{4d}{3}=\frac{16d}{3u}$ | A1<br>(6) | |
| | | [16] | |

| Question Number | Scheme | Marks |
|---|---|---|
| **6a** |  | |
| | CLM: $mv+kmw=mw+2kmw$<br>Impact law: $2w-w=\frac{2}{3}(v-w)$ $\left(\frac{2}{3}v=\frac{5}{3}w\right)$<br>$v=\frac{5}{2}w \quad \Rightarrow \quad k=\frac{3}{2}$ | M1A1<br>M1A1<br>M1A1<br>**(6)** |
| **6b** | Speed of $Q$ at second impact $=\frac{2w}{3}$<br>Time for $Q$ to reach wall $=\frac{d}{2w}$<br>Distance travelled by $P$ plus $Q$ after hitting wall to second impact<br>$\Rightarrow wt+\frac{2}{3}w\left(t-\frac{d}{2w}\right)=d$<br>$\Rightarrow t=\frac{4d}{5w}$ | B1<br>B1<br>M1A1<br>A1<br>**(5)** |
| **Alt1** | Speed of $Q$ at second impact $=\frac{2w}{3}$<br>Time for $Q$ to reach wall $=\frac{d}{2w}$<br>Time $t$ from wall to second impact $\Rightarrow \frac{2w}{3}t+wt=\frac{d}{2}$ $\left(t=\frac{3d}{10w}\right)$<br>Total time $=\frac{d}{2w}+\frac{3d}{10w}=\frac{4d}{5w}$ | B1<br>B1<br>M1A1<br>A1<br>**(5)** |
| **Alt 2** | Speed of $Q$ at second impact $=\frac{2w}{3}$<br>Time for $Q$ to reach wall $=\frac{d}{2w}$<br>Time from wall to second impact $=\frac{\text{distance apart}}{\text{speed of approach}}=\frac{d/2}{w+\frac{2w}{3}}$<br>Total time $=\frac{d}{2w}+\frac{3d}{10w}=\frac{4d}{5w}$ | (B1)<br>(B1)<br>(M1A1)<br>(A1) |

| | | |
|---|---|---|
| **Alt 3** | Speed of Q at second impact $= \frac{2w}{3}$ | (B1) |
| | Time for $Q$ to reach wall $= \frac{d}{2w}$ | (B1) |
| | $AB = x \Rightarrow$ time for P to travel A to B $= \frac{x}{w}$ | |
| | Time for Q to travel A to B $= \frac{d}{2w} + \frac{d-x}{2w/3}\left(= \frac{4d-3x}{2w}\right)$ | (M1) |
| | $\frac{x}{w} = \frac{4d-3x}{2w} \Rightarrow x = \frac{4d}{5}$ | (A1) |
| | $\Rightarrow t = \frac{4d}{5w}$ | (A1) |
| | | Total 11 |

| **Notes** | |
|---|---|
| **a** | |
| M1 | Conservation of momentum. Must have 4 terms. All terms must have $m$ or none. |
| A1 | Correct equation. |
| M1 | Impact law. Must be the correct way up. |
| A1 | Correct equation. Note, speeds and directions are defined in the question, so the signs must be correct. |
| M1 | Solve equations to find $k$. |
| A1 | $\frac{3}{2}$ (accept any equivalent) |
| **b** | |
| All methods – The M mark requires a complete method to find the total time, so the line of working with the first A mark attached might not be sufficient to earn the M mark. | |
| B1 | Speed of $Q$ at second impact $= \frac{2w}{3}$ seen in working. Must be seen, not implied. (i.e. $3v=2w$ scores B0). |
| B1 | Time for $Q$ to reach wall $= \frac{d}{2w}$. Must be seen, not implied. (i.e. $2wt=d$ scores B0). |
| M1 | Complete method to find total time. If time from wall found, the method must be completed to earn this mark. Condone numerical slips if a clearly sound strategy is attempted |
| A1 | Correct initial equation to find either for total time or time from wall to impact. |
| A1cao | total time $= \frac{4d}{5w}$ |