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\begin{tabular}{|c|c|c|c|c|c|}
\hline 1 \& \begin{tabular}{l}
\[
\mathrm{v}_{v}=15 \sin 60-0.9 \mathrm{~g}
\]
\[
\tan \theta=(15 \sin 60-0.9 \mathrm{~g}) /(15 \cos 60)
\] \\
\(\theta=28(.0)^{\circ}\) above horizontal
\end{tabular} \& \begin{tabular}{l}
B1 \\
M1 \\
A1 \\
A1
\end{tabular} \& [4] \& \begin{tabular}{l}
\[
3.99
\] \\
Ratio of vert and horiz speeds
\end{tabular} \& \\
\hline 2 \& \[
\begin{aligned}
\& 0.3 \mathrm{~g} \times(0.6+\mathrm{e})=45 \mathrm{e}^{2} /(2 \times 0.6) \\
\& 37.5 \mathrm{e}^{2}-3 \mathrm{e}-1.8=0 \\
\& \mathrm{e}=0.263 \mathrm{~m}
\end{aligned}
\] \& \[
\begin{aligned}
\& \text { M1 } \\
\& \text { A1 } \\
\& \text { M1 } \\
\& \text { A1 }
\end{aligned}
\] \& [4] \& \begin{tabular}{l}
PE/EE equated \\
Solves 3 term quadratic equation
\end{tabular} \& 4 \\
\hline \begin{tabular}{l}
3 (i) \\
(ii)
\end{tabular} \& \[
\begin{aligned}
\& \mathrm{v}=25 \mathrm{~ms}^{-1} \\
\& \cos \theta=5 / 25 \\
\& \theta=78.5^{\circ}(\text { with horizontal }) \\
\& 30=\mathrm{gt}^{2} / 2 \\
\& \mathrm{~s}=5 \times 2.45 \\
\& \mathrm{~s}=12.2 \mathrm{~m}
\end{aligned}
\] \& \begin{tabular}{l}
B1 \\
M1 \\
A1 \\
M1 \\
M1 \\
A1
\end{tabular} \& [3]
[3] \& \begin{tabular}{l}
\[
\sqrt{\left(5^{2}+2 g \times 30\right)}
\] \\
Forms a relevant trig ratio \\
Ignore above/below \\
\(\mathrm{t}=2.45\), award if found in (i) \\
\(5 \times\) time of flight
\end{tabular} \& 6 \\
\hline \begin{tabular}{l}
4 (i) \\
(ii) \\
(iii)
\end{tabular} \& \[
\begin{aligned}
\& \cos \theta=0.8, \sin \theta=0.6 \text { or } \\
\& \cos \phi=0.6, \sin \phi=0.8 \\
\& \mathrm{~T} \cos \theta=0.2 \mathrm{~g} \text { or } \mathrm{T} \sin \phi=0.2 \mathrm{~g} \\
\& \mathrm{~T}=2.5 \mathrm{~N} \\
\& 2.5 \sin \theta \text { or } 2.5 \cos \phi=0.2 \omega^{2} \times 0.3 \\
\& \omega=5 \mathrm{rads}^{-1} \\
\& \mathrm{R}+2.5 \sin \theta=0.2 \times 1.8^{2} / 0.3 \\
\& \text { or } \mathrm{R}+2.5 \cos \phi=0.2 \times 1.8^{2} / 0.3 \\
\& \mathrm{R}=0.66 \mathrm{~N}
\end{aligned}
\] \& \begin{tabular}{l}
B1 \\
M1 \\
A1 \\
M1 \\
A1 \\
M1 \\
A1 \\
A1
\end{tabular} \& \begin{tabular}{l}
[3] \\
[2] \\
[3]
\end{tabular} \& \begin{tabular}{l}
Either \(\theta=\) string angle with vert or \(\phi=\) string angle with horiz Resolves T vertically \\
N2L with acc \({ }^{n}=2 \omega^{2} \times 0.3\) \\
N2L with \(2+\) ve radial forces
\end{tabular} \& 8 \\
\hline \begin{tabular}{l}
5 (i) \\
(iia) \\
(iib) \\
(iic) \\
(iii)
\end{tabular} \& \[
\begin{aligned}
\& 0.4 \mathrm{~g}=20 \mathrm{e} / 0.5 \\
\& \mathrm{OP}=0.6 \mathrm{~m} \\
\& 4 \mathrm{~N} \\
\& 0 \mathrm{~N} \\
\& \mathrm{~T}=0.4 \mathrm{~g}-20 \times 0.04 / 0.5 \\
\& \mathrm{~T}=2.4 \mathrm{~N} \\
\& \\
\& 0.4 \mathrm{v}^{2} / 2=0.4 \mathrm{~g}(0.6-0.54) \\
\& -\left[20(0.1)^{2} /(2 \times 0.5)-20(0.04)^{2} /(2 \times 0.5)\right] \\
\& \mathrm{v}=0.6 \mathrm{~ms}^{-1}
\end{aligned}
\] \& \begin{tabular}{l}
M1 \\
A1ft \\
B1 \\
B1 \\
M1 \\
A1 \\
M1 \\
A1 \\
A1
\end{tabular} \& [2]
[4]

[3] \& | $\begin{aligned} & \text { Weight }=\lambda \text { ext } / \mathrm{L}(\mathrm{e}=0.1) \\ & 0.5+\operatorname{cv}(\mathrm{e}) \end{aligned}$ |
| :--- |
| Weight $(P)-\lambda e x t / L$ |
| $\mathrm{PE} / \mathrm{KE} / \mathrm{EE}$ energy conservation EE change (0.168 J) | \& 9 \\

\hline
\end{tabular}

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| 6 (i) | $380 \mathrm{G}+16 \times[0.4+(0.8-3 \times 0.8 / 4)]$ | M1 |  | Table of moments idea |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | $=54 \times(1.2-3 \times 1.2 / 4)$ | A1 |  |  |  |
|  | $\mathrm{OG}=0.174$ | A1 | [3] | 0.17368.. |  |
| (iia) | $\mu(=4 / 16)=0.25,1 / 4$ | B1 | [1] |  |  |
| (iib) | $4(1.2-0.4) \prec 16(1.2-0.4) \tan \theta$ | M1 |  | Moment equation involving toppling |  |
|  | $\theta \succ 14.0$ AG | A1 | [2] |  |  |
| (iii) | $\cos \theta=(0.8 / \cos \theta) /(1.2-0.17368 .$. | M1 |  | Uses a ratio of relevant distances |  |
|  | $\cos ^{2} \theta=0.8 / 1.02631 . .$ | A1 |  | Accept unsimplified version with single trig ratio |  |
|  | $\theta=28(.0)^{\circ}$ | A1 | [3] |  | 9 |
| OR | $\tan \theta=(0.4-0.17368 .) /.(0.8 \tan \theta)$ | A1 |  | Uses a ratio of relevant distances |  |
|  | $\tan ^{2} \theta=0.22631 . . / 0.8$ | A1 |  | Accept unsimplified version with trig ratio |  |
|  | $\theta=28(.0)^{\circ}$ | A1 |  |  |  |
| OR | $\begin{aligned} & \sin \theta \\ & =[(0.4-0.17368 .) / \sin \theta] /(1.2-0.17368 .) \end{aligned}$ | M1 |  | Uses a ratio of relevant distances |  |
|  | $\sin ^{2} \theta=0.2631 . . / 1.02631 . .$ | A1 |  | Accept unsimplified version with single trig ratio |  |
|  | $\theta=28(.0)^{\circ}$ | A1 |  |  |  |
| 7 (i) | 0.2a $=-\mathrm{k} /(1-x)$ | M1 |  | N2L, single force |  |
|  | $\begin{aligned} & \mathrm{a}=-5 \mathrm{k} /(1-x) \\ & \int v \mathrm{~d} v=-5 \mathrm{k} \int 1 /(1-x) \mathrm{d} x \end{aligned}$ | M1 |  | Attempts $\int$, accept use of $\mathrm{d} v / \mathrm{d} t$ |  |
|  | $v^{2} / 2=5 \mathrm{kln}(1-x)(+\mathrm{c})$ | A1 |  |  |  |
|  | $x=0, \mathrm{v}=1.2$, hence $\mathrm{c}=0.72$ | M1 |  | $\left[v^{2} / 2\right]_{1.2}^{0}=[5 \mathrm{kln}(1-x)]_{0}^{0.55}$ |  |
|  | $5 \mathrm{k} \ln (1-0.55)+0.72=0$ | DM1 |  |  |  |
|  | $\mathrm{k}=0.1803$ AG | A1 | 6 |  |  |
| (ii) | $0.2 v \mathrm{~d} v / \mathrm{d} x=0.2 \mathrm{~g}-0.1803 /(1-x)$ | M1 |  | N2L, difference of 2 forces |  |
|  | $0.2 v^{2} / 2=0.2 \mathrm{~g} x+0 .(1-x)(+\mathrm{c})$ | A1 |  | Accept omission of c |  |
|  | $0.2 v^{2} / 2=0.2 \mathrm{~g} x 0.1+0.1803 \ln (1-0.1)$ | M1 |  | $\mathrm{nb} \mathrm{c}=0$, so can be omitted/lost |  |
|  | $v=1.35 \mathrm{~ms}^{-1}$ | A1 | 4 | 1.345 | 10 |

