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| $\begin{array}{ll} 1 \quad \mathrm{v}_{\text {down }}=2 \mathrm{~g} \\ & \tan \theta=2 \mathrm{~g} / 12 \\ & \theta=59.0^{\circ} \end{array}$ | B1 <br> M1 <br> A1 <br> [3] | $\tan \alpha=12 / 2 \mathrm{~g}$ |
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| $2 \quad \mathrm{X}_{G}=20 / 4 \mathrm{n}=(20 / 4) \mathrm{mg} .$ | B1 <br> M1 <br> A1 <br> A1 <br> [4] | $5$ <br> Attempt at moments about P |
| $3 \quad \text { (i) } \begin{aligned} & 15=40 \tan \theta-940^{2} /\left(2 \times 40^{2} \cos ^{2} \theta\right) \\ & \\ & 15=40 \tan \theta-5 \sec ^{2} \theta \\ & \\ & \tan ^{2} \theta-8 \tan \theta+4=0 \end{aligned}$ | AGM1 <br> M1 <br> A1 <br> $[3]$ | Substitutes in projectile equation Uses $\sec ^{2} \theta=1+\tan ^{2} \theta$ |
| (ii) $\begin{aligned} & \theta=\tan ^{-1}(4+/-2 \sqrt{3}) \\ & \theta=28.2^{\circ} \text { or } 82.4^{\circ} \\ & \mathrm{R}=40^{2} \sin \left(2 \times 28.2^{\circ}\right) / \mathrm{g} \text { or } \\ & \mathrm{R}=40^{2} \sin \left(2 \times 82.4^{\circ}\right) / \mathrm{g} \end{aligned}$ $\begin{aligned} & \mathrm{R}=133 \text { or } \mathrm{R}=41.9 \text { (or } 42.0) \\ & \text { Difference }=91.1 \mathrm{~m} \end{aligned}$ | M1 <br> A1 <br> M1 <br> A1 <br> A1 <br> [5] | Solves quadratic equation for $\theta$ <br> Valid formula for one range $\begin{aligned} & 0=\mathrm{Rtan} 28.2^{\circ}-\mathrm{gR}^{2} /\left(2 \times 40^{2} \cos 28.2^{\circ}\right) \\ & \text { or } 0=\operatorname{rtan} 82.4^{\circ}-\mathrm{gr}^{2} /\left(2 \times 40^{2} \cos 82.4^{\circ}\right) \end{aligned}$ <br> Using exact angles. Allow + /- 0.2 |
| $4 \quad \text { (i) } \begin{aligned} & \mathrm{d}=2 \times 0.3 \sin (\pi / 2) /(3 \pi / 2) \\ & \mathrm{T}(0.6 \cos 30)= \\ & 0.4 \mathrm{~g}\left(0.3 \sin 30^{\circ}+0.1273 \cos 30^{\circ}\right) \\ & \mathrm{T}=2 \mathrm{~N} \end{aligned}$ |  B1 <br> M1  <br> AG A1 <br>  A1 <br>  $[4]$ | $\mathrm{d}=0.1273$ $2.003 \ldots$ |
| $\text { (ii) } \begin{aligned} \mathrm{R} & \left.=\sqrt{\left(2^{2}\right.}+(0.4 \mathrm{~g})^{2}\right) \text { or } \tan \theta=2 /(0.4 \mathrm{~g}) \\ \mathrm{R} & =4.47 \mathrm{~N} \\ \theta & =26.6^{\circ} \text { (with vertical) } \end{aligned}$ | M1 <br> A1 <br> A1 <br> [3] | Either (or $\tan \alpha=0.4 \mathrm{~g} / 2$ with horizontal) $\alpha=63.4^{\circ}(\text { with horizontal })$ |
| $5 \quad \text { (i) } \begin{array}{ll}  & 3 \mathrm{~T} \cos 30^{\circ}-\mathrm{T} \cos 30^{\circ}=0.4 \mathrm{~g} \\ & \mathrm{~T}=2.31 \\ & 0.4 \times 6^{2} / \mathrm{r}=4 \mathrm{~T} \sin 30^{\circ} \\ & \mathrm{r}=3.12 \end{array}$ | M1 <br> A1 <br> M1 <br> A1 <br> [4] | Resolves vertically, 3 terms <br> Newton's $2^{\text {nd }}$ Law horizontally |
| $\text { (ii) } \begin{aligned} \mathrm{T}_{P B}=0 \\ \mathrm{~T} \cos 30^{\circ}=0.4 \mathrm{~g}(\mathrm{~T}=4.62) \\ 0.4 \mathrm{v}^{2} / 3.12=\mathrm{Tsin} 30^{\circ} \\ \mathrm{v}=4.24 \mathrm{~ms}^{-1} \end{aligned}$ | B1 <br> M1 <br> M1 <br> A1 <br> [4] | Resolves vertically, 2 terms <br> Newton's $2^{\text {nd }}$ Law horizontally |


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| 6 (i) $\begin{aligned} & 0.5 \mathrm{vdv} / \mathrm{dx}=-3 \mathrm{v}^{1 / 2} \\ & \int \mathrm{v}^{1 / 2} \mathrm{dv}=-\int 6 \mathrm{dx} \\ & \mathrm{v}^{3 / 2} /(3 / 2)=-6 \mathrm{x}(+\mathrm{c}) \\ & \mathrm{x}=0, \mathrm{v}=9 \text { hence } \mathrm{c}=18 \\ & \mathrm{v}^{3 / 2}=3(18-6 \mathrm{x}) / 2 \\ & \mathrm{v}=(27-9 \mathrm{x})^{2 / 3} \end{aligned}$ | AG | $\begin{aligned} & \text { M1 } \\ & \text { M1 } \\ & \text { A1 } \\ & \text { M1 } \\ & \text { A1 } \\ & {[5]} \end{aligned}$ | Newton's $2^{\text {nd }}$ Law with $a=v d v / d x$ Separates variables and integrates <br> Or uses limits |
| :---: | :---: | :---: | :---: |
| $\text { (ii) } \begin{aligned} & \mathrm{dx} / \mathrm{dt}=(27-9 \mathrm{x})^{2 / 3} \\ & \quad \begin{array}{l} (27-9 \mathrm{x})^{-2 / 3} \mathrm{dx}=\int \mathrm{dt} \\ (27-9 \mathrm{x})^{1 / 3} /-3=\mathrm{t}(+\mathrm{c}) \\ \mathrm{t}=0, \mathrm{x}=0 \text { hence } \mathrm{c}=-1 \\ \mathrm{t} \end{array}=0.5, \mathrm{x}=2.625 \end{aligned}$ |  | M1 <br> A1ft <br> M1 <br> A1 <br> [4] | $\begin{aligned} & 0.5 \mathrm{dv} / \mathrm{dt}=-3 \mathrm{v}^{1 / 2} \\ & \int v^{-1 / 2} \mathrm{dv}=-\int 6 d t \\ & \mathrm{v}^{1 / 2}=-3 \mathrm{t}+\mathrm{c} \\ & \mathrm{t}=0, \mathrm{v}=9 \text { hence } \mathrm{c}=3 \text { and } \mathrm{t}=0.5, \\ & \text { giving } \mathrm{v}=2.25 \\ & \mathrm{v}=2.25, \mathrm{x}=2.625 \end{aligned}$ |
| $7 \text { (i) } \begin{array}{ll}  & 0.4 \mathrm{v}^{2} / 2+24 \mathrm{x}^{2} /(2 \times 3) \\ & 0.4 \mathrm{~g}(3+\mathrm{x})+0.4 \times 2^{2} / 2 \\ & \mathrm{v}^{2}=64+20 \mathrm{x}-20 \mathrm{x}^{2} \end{array}$ | AG | M1 <br> A2 <br> A1 <br> [4] | PE, EE, KE terms <br> -1 each error to zero |
| $\text { (ii) } \begin{aligned} & 2 \mathrm{vdv} / \mathrm{dx}=20-40 \mathrm{x}=0 \\ & \mathrm{x}=0.5 \\ & \mathrm{v}=8.31 \end{aligned}$ |  | M1 <br> A1ft <br> A1 [3] | $0.4 \mathrm{~g}=24 \mathrm{x} / 3$ |
| $\text { (iii) } \begin{aligned} & 20 \mathrm{x}^{2}-20 \mathrm{x}-64=0 \\ & \mathrm{x}=2.357 \\ & \mathrm{~T}=24 \times 2.357 / 3 \\ & \mathrm{~T}=18.9 \end{aligned}$ |  | M1 <br> A1 <br> M1 <br> A1 <br> [4] | And attempts to solve |

