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|---|---|---|---|---|---|---|
| **1** | **(i)** | $x = (20\cos45)t$ | B1 | | Or sin45, $1/\sqrt{2}$ , 0.707 | |
| | | $y = (20\sin45)t - gt^2/2$ | B1 | [2] | Or cos45, $1/\sqrt{2}$ , 0.707. | |
| | **(ii)** | $y = (20\sin45)(x/(20\cos45)) - g[x/(20\cos45)]^2/2$ | M1 | | Substitutes $t = x/(20\cos45)$ at least once | |
| | | $y = x - x^2/40$ AG | A1 | [2] | Only from g = 10 | |
| | **(iii)** | $x = 40$ m | B1 | [1] | | **[5]** |
| **2** | **(i)** | $T = 19.2 \times (2.7 - 1.2)/1.2$ | B1 | | T = 24 N | |
| | | $0.4a = 0.4g + T$ | M1 | | Newton's Second Law with 3 terms | |
| | | $a = 70$ ms$^{-2}$ | A1 | [3] | | |
| | **(ii)** | $19.2(2.7 - 1.2)^2/(2 \times 1.2)$ | B1 | | Initial EE = 18 | |
| | | | M1 | | For a 3 term energy equation | |
| | | $0.4v^2/2 = 0.4g \times 2.7 + 19.2 \times (2.7 - 1.2)^2/(2 \times 1.2)$ | A1 | | | |
| | | $v = 12$ ms$^{-1}$ | A1 | [4] | | **[7]** |
| **3** | **(i)** | | M1 | | Table of values or a moment equation | |
| | | $0.2 \times 0.1 + 0.3 \times 0 = d(0.2+0.3)$ | A1 | | Accept no mention of $0.3 \times 0$ | |
| | | $d = 0.04$ m | A1 | [3] | | |
| | **(ii)** | $4 \times 0.3 = 0.04W$ | M1 | | Moments about A | |
| | | $W = 30$ N | A1ft | [2] | ft 1.2/cv(d(i)) | |
| | **(iii)** | $\mu = 4/30$ | M1 | | 4/cv(W(ii)) | |
| | | $\mu = 0.133$ | A1 | [2] | Accept 2/15 | **[7]** |
| **4** | **(i)** | $a = 10 - 0.45v$ AG | B1 | [1] | 0.2a = 0.2g – 0.09v or similar should be seen | |
| | **(ii)** | $\int 1/(10-0.45v)dv = \int dt$ | M1 | | An attempt at integration needed | |
| | | $-\ln(10 - 0.45v)/0.45 = t$ (+c) | A1 | | | |
| | | t = 0, v = 4, c = –4.67(58..) | DM1 | | Attempts to find c or uses correct limits | |
| | | $-\ln(10 - 0.45v)/0.45 = 1.5 - 4.676$ | M1 | | Uses t = 1.5 and evaluated c | |

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|---|---|---|---|---|---|---|
| | | v = 12.9 or 13.0 | A1 | [5] | | **[6]** |
| **5** | **(i)** | $v_y = 50\sin40 - 2.5g$ | B1 | | Vertical component speed (=7.139…) | |
| | | $v^2 = (50\sin40 - 2.5g)^2 + (50\cos40)^2$ | M1 | | Uses Pythagoras with correct horizontal component | |
| | | $v = 39(.0)\ ms^{-1}$ | A1 | [3] | | |
| | **(ii)** | $x = 50\cos40 \times 2.5$ | B1 | | Horizontal displacement at 2.5s (=95.75..) | |
| | | $y = 50\sin40 \times 2.5 - 2.5^2 g/2$ | B1 | | (=49.09..) | |
| | | $\tan\theta = 49.09/95.75$ | M1 | | Appropriate ratio to find angle | |
| | | $\theta = 27.1^\circ$ | A1 | [4] | | **[7]** |
| **6** | **(i)** | Radial $acc^n = 1.2^2/(0.2\cos30)$ | B1 | | Radial $acc^n = 8.31..ms^{-2}$ | |
| | | $T\cos30 = 0.3 \times 1.2^2/(0.2\cos30)$ | M1 | | Component of tension = m × radial $acc^n$ | |
| | | T = 2.88 N | A1 | [3] | | |
| | **(ii) (a)** | $T\cos60 = 0.3g$ | M1 | | Uses T max in limiting case when R = 0 | |
| | | T = 6 | A1 | | May be implied | |
| | | $6\cos30 = 0.3\omega^2(0.2\cos30)$ | M1 | | Component of max T = m × maximum radial $acc^n$ | |
| | | $\omega = 10$ AG | A1 | [4] | From g = 10 only | |
| **OR** | | $T\cos30 = 0.3 \times 10^2(0.2\cos30)$ | M1 | | Finds T max from m × max(RA) | |
| | | T = 6 | A1 | | | |
| | | $R + 6\cos60 = 0.3g$ | M1 | | Resolves vertically with T max | |
| | | R = 0 and a higher value of $\omega$ makes R negative which is impossible | A1 | | Additional justification needed of inequality | |
| | **(ii) (b)** | $KE = 0.3(10 \times 0.2\cos30)^2/2$ | M1 | | Attempt at KE with v = 10 × radius | |
| | | KE = 0.45 J | A1 | [2] | | **[7]** |
| **7** | | $OG = 2r\sin(\pi/3)/(3\pi/3)$ | B1 | | Centre of mass from O | |
| | | $15r\cos(\pi - 2\pi/3)$ | B1 | | Moment of 15 N about O | |
| | | $20 \times OG\cos(\pi/3 - \theta)$ | B1ft | | Moment of weight about O, ft cv(OG) if used | |

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|---|---|---|---|---|---|
| | | M1 | | Uses moments, including 15 N and 20 N | |
| | $15r\cos(\pi/3) \leqslant 20 \times 2r\sin(\pi/3)/\pi \times \cos(\pi/3 - \theta)$ | A1ft | | Accept $\prec$, =, $\succ$ as alternative to $\leqslant$ | |
| | $\cos(\pi/3 - \theta) \geqslant 0.68(017..)$ | A1 | | Accept $\succ$, =, $\prec$ as an alternative to $\geqslant$ | |
| | $\pi/3 - \theta \leqslant 0.82(279..)$ | M1 | | Solves for $\theta$, equation or inequality | |
| | $\theta = 0.224$ | A1 | | Correct value | |
| | $\theta \geq 0.224$ | A1 | [9] | Correct sign, accept $\succ$<br>**SR deduct 1 mark for assuming r = 1** | **[9]** |

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