| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 11(b) | Correct derivative: $4\pi r - 660r^{-2}$, isw | **B2** | **B1** for one correct term |
| | $4\pi r - \frac{660}{r^2} = 0$ and solves for $r$ | **M1** | **FT** *their* derivative providing that at least one term is correct |
| | $r = \sqrt[3]{\frac{660}{4\pi}}$ oe, isw or 3.74 or 3.744[94…] rot to 3 or more dp | **A1** | |
| | Second derivative $\frac{d^2S}{dr^2} = 4\pi + 1320r^{-3}$<br>**and**<br>When $r = 3.74$, $\frac{d^2S}{dr^2} > 0$ oe [hence minimum]<br><br>or<br>$\frac{d^2S}{dr^2} = 12\pi$ or 37 to 38 [hence minimum]<br>or<br>as $r > 0$, $\frac{d^2S}{dr^2} > 0$ [hence minimum]<br>OR<br>correctly finds the values of the first derivative at<br>3.74 oe $\pm h$, where $h$ is small [hence minimum] | **A1** | **dep** on previous mark |
| 12(a) | $\begin{pmatrix} 5\sqrt{3}\cos 60 \\ 5\sqrt{3}\sin 60 \end{pmatrix}$ oe or $\begin{pmatrix} \frac{5\sqrt{3}}{2} \\ \frac{15}{2} \end{pmatrix}$ oe<br><br>$\begin{pmatrix} 10\cos 30 \\ 10\sin 30 \end{pmatrix}$ oe or $\begin{pmatrix} 5\sqrt{3} \\ 5 \end{pmatrix}$ oe | **2** | **B1** for each or for correct components not stated in vector form |

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|---|---|---|---|
| 12(b) | $t\begin{pmatrix}\frac{5\sqrt{3}}{2}\\ \frac{15}{2}\end{pmatrix}$ oe and $\begin{pmatrix}0\\1000\end{pmatrix}+(t-100)\begin{pmatrix}5\sqrt{3}\\5\end{pmatrix}$ oe | **2** | **B1** for each |
| | $\frac{5\sqrt{3}}{2}t = 5\sqrt{3}(t-100)$ and $\frac{15}{2}t = 1000 + 5(t-100)$ oe<br>OR finds the magnitude $d$, or $d^2$, for $\begin{pmatrix}\frac{5\sqrt{3}}{2}t\\ \frac{15}{2}t\end{pmatrix}-\begin{pmatrix}5\sqrt{3}t-500\sqrt{3}\\5t+500\end{pmatrix}$ and equates to 0 | **2** | **M1 FT** for one correct equation from *their* displacement vectors or for *their* $\begin{pmatrix}\frac{5\sqrt{3}}{2}t\\ \frac{15}{2}t\end{pmatrix}-\begin{pmatrix}5\sqrt{3}t-500\sqrt{3}\\5t+500\end{pmatrix}$ |
| | $t = 200$ obtained from both equations OR as the only solution from $d = 0$ [hence collide] | **A1** | |
| | **Alternative method** | | |
| | $(t+100)\begin{pmatrix}\frac{5\sqrt{3}}{2}\\ \frac{15}{2}\end{pmatrix}$ oe and $\begin{pmatrix}0\\1000\end{pmatrix}+t\begin{pmatrix}5\sqrt{3}\\5\end{pmatrix}$ oe | **(2)** | **B1** for each |
| | $\frac{5\sqrt{3}}{2}(t+100) = 5\sqrt{3}t$ and $\frac{15}{2}(t+100) = 1000 + 5t$ oe<br>OR finds the magnitude $d$, or $d^2$, for $\begin{pmatrix}\frac{5\sqrt{3}}{2}t+250\sqrt{3}\\7.5t+750\end{pmatrix}-\begin{pmatrix}5\sqrt{3}t\\5t+1000\end{pmatrix}$ and equates to 0 | **(2)** | **M1 FT** for one correct equation from *their* displacement vectors or for *their* $\begin{pmatrix}\frac{5\sqrt{3}}{2}t+250\sqrt{3}\\7.5t+750\end{pmatrix}-\begin{pmatrix}5\sqrt{3}t\\5t+1000\end{pmatrix}$ |
| | $t = 100$ obtained from both equations OR as the only solution from $d = 0$ [hence collide] | **(A1)** | |

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| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 13 | $\sin\theta(2\sin^2\theta - 3\cos\theta)$ [= 0] | **B1** | |
| | [$\sin\theta = 0$] $\theta = 0$ and no other solutions in range from this factor | **B1** | |
| | $2(1 - \cos^2\theta) = 3\cos\theta$ oe | **M1** | |
| | Write in solvable form:<br>$-2\cos^2\theta - 3\cos\theta + 2$ [= 0] oe | **A1** | |
| | Factorises or solves *their* 3-term quadratic in $\cos\theta$ e.g.<br><br>$(2\cos\theta - 1)(\cos\theta + 2)$ [= 0] | **M1** | |
| | $\theta = \pm\frac{\pi}{3}$ or ± 1.05 or ± 1.047[19…] and no other solutions in range from this factor | **A1** | |

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