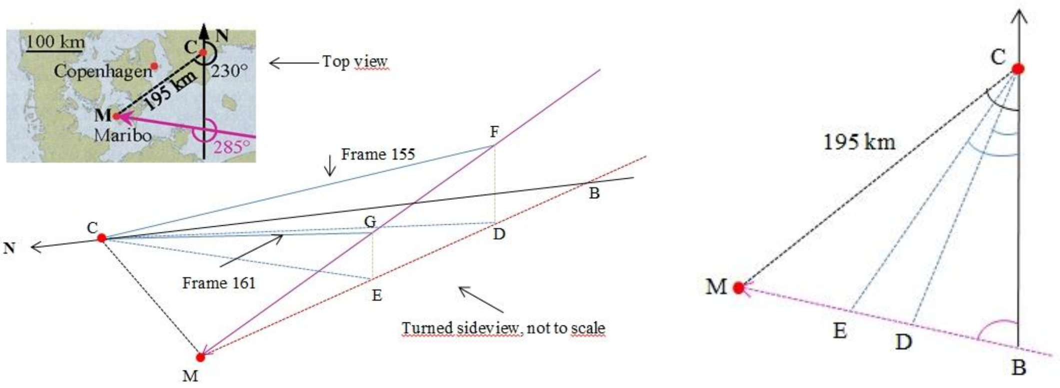
Solutions

1.1	 Top view: Triangle MCB: $\lvert CM\rvert = 195$ km, $\angle MCB = 230° - 180° = 50°$, and $\angle MBC = 75°$, so $\angle CMB = 180° - 75° - 50° = 55°$. Then $\lvert CB\rvert = \frac{\lvert CM\rvert \sin(\angle CMB)}{\sin(\angle MBC)} = 165.4$ km. Triangle DCB: $\lvert CB\rvert = 165.4$ km, $\angle DCB = 215° - 180° = 35°$,and $\angle DBC = 75°$, so $\angle CDB = 180° - 75° - 35° = 70°$. Then $\lvert CD\rvert = \frac{\lvert CB\rvert \sin(\angle DBC)}{\sin(\angle CDB)} = 170.0$ km. Triangle ECB: $\lvert CB\rvert = 165.4$ km, $\angle ECB = 221° - 180° = 41°$, and $\angle EBC = 75°$, so $\angle CEB = 180° - 75° - 41° = 64°$. Then $\lvert CE\rvert = \frac{\lvert CB\rvert \sin(\angle EBC)}{\sin(\angle CEB)} = 177.7$ km. Triangle ECD:$\angle ECD = 41° - 35° = 6°$. Horisontal distance travelled by Maribo:$\lvert DE\rvert = \frac{\lvert DC\rvert \sin(\angle ECD)}{\sin(\angle CED)} = 19.77$ km Side view: Triangle CFD: $\lvert FD\rvert = \lvert CD\rvert \tan(\angle FCD) = 59.20$ km Triangle CGE: $\lvert GE\rvert = \lvert CE\rvert \tan(\angle GCE) = 46.62$ km Thus vertical distance travelled by Maribo: $\lvert FD\rvert - \lvert GE\rvert = 12.57$ km. Total distance travelled by Maribo from frame 155 to 161: $\lvert FG\rvert = \sqrt{\lvert DE\rvert^2 + (\lvert FD\rvert - \lvert GE\rvert)^2} = 23.43$ km. The speed of Maribo is $v = \frac{23.43\ \mathrm{km}}{2.28\ \mathrm{s} - 1.46\ \mathrm{s}} = 28.6\ \mathrm{km/s}$	1.2

1.2a	Newton's second law: $m_M \frac{dv}{dt} = -k\rho_{atm}\pi R_M^2 v^2$ yields $\frac{1}{v^2} dv = -\frac{k\rho_{atm}\pi R_M^2}{m_M} dt$. By integration $t = \frac{m_M}{k\rho_{atm}\pi R_M^2}\left(\frac{1}{0.9} - 1\right)\frac{1}{v_M} = 0.88$ s.	0.7
1.2b	$\frac{E_{kin}}{E_{melt}} = \frac{\frac{1}{2}v_M^2}{c_{sm}(T_{sm} - T_0) + L_{sm}} = \frac{4.2\times10^8}{2.1\times10^6} = 2.1 \times 10^2 \gg 1.$	0.3

1.3a	$[x]=[t]^{\alpha}[\rho_{\mathrm{sm}}]^{\beta}[c_{\mathrm{sm}}]^{\gamma}\,[k_{\mathrm{sm}}]^{\delta}=[\mathrm{s}]^{\alpha}[\mathrm{kg\,m^{-3}}]^{\beta}[\mathrm{m^2\,s^{-2}K^{-1}}]^{\gamma}\,[\mathrm{kg\,m\,s^{-3}K^{-1}}]^{\delta}$, so $[\mathrm{m}]=[\mathrm{kg}]^{\beta+\delta}[\mathrm{m}]^{-3\beta+2\gamma+\delta}[\mathrm{s}]^{\alpha-2\gamma-3\delta}[\mathrm{K}]^{-\gamma-\delta}$. Thus $\beta+\delta=0,\;\; -3\beta+2\gamma+\delta=1,\;\; \alpha-2\gamma-3\delta=0$, and $\;-\gamma-\delta=0$. From which $(\alpha,\beta,\gamma,\delta)=\left(+\frac{1}{2},-\frac{1}{2},-\frac{1}{2},+\frac{1}{2}\right)$ and $x(t)\approx\sqrt{\frac{k_{\mathrm{sm}}t}{\rho_{\mathrm{sm}}c_{\mathrm{sm}}}}$.	0.6
1.3b	$x(5\ \mathrm{s})=1.6\ \mathrm{mm}$ $\quad x/R_{\mathrm{M}}=1.6\ \mathrm{mm}/130\ \mathrm{mm}=0.012$.	0.4

1.4a	Rb-Sr decay scheme: ${}^{87}_{37}\mathrm{Rb}\rightarrow{}^{87}_{38}\mathrm{Sr}\;+\;{}^{\;0}_{-1}\mathrm{e}+\;\bar{\nu}_{\mathrm{e}}$	0.3
1.4b	$N_{87\mathrm{Rb}}(t)=N_{87\mathrm{Rb}}(0)\mathrm{e}^{-\lambda t}$and Rb→Sr: $N_{87\mathrm{Sr}}(t)=N_{87\mathrm{Sr}}(0)+[N_{87\mathrm{Rb}}(0)-N_{87\mathrm{Rb}}(t)]$. Thus $N_{87\mathrm{Sr}}(t)=N_{87\mathrm{Sr}}(0)+(\mathrm{e}^{\lambda t}-1)N_{87\mathrm{Rb}}(t)$, and dividing by $N_{86\mathrm{Sr}}$ we obtain the equation of a straight line: $\frac{N_{87\mathrm{Sr}}(t)}{N_{86\mathrm{Sr}}}=\frac{N_{87\mathrm{Sr}}(0)}{N_{86\mathrm{Sr}}}+(\mathrm{e}^{\lambda t}-1)\frac{N_{87\mathrm{Rb}}(t)}{N_{86\mathrm{Sr}}}$.	0.7
1.4c	Slope: $\mathrm{e}^{\lambda t}-1=a=\frac{0.712-0.700}{0.25}=0.050$ and $T_{½}=\frac{\ln(2)}{\lambda}=4.9\times10^{10}$ year. So $\tau_M=\ln(1+a)\frac{1}{\lambda}=\frac{\ln(1+a)}{\ln(2)}T_{½}=3.4\times10^{9}$ year .	0.4

1.5	Kepler's 3rd law on comet Encke and Earth, with the orbital semi-major axis of Encke given by $a=\frac{1}{2}(a_{\mathrm{min}}+a_{\mathrm{max}})$. Thus $t_{\mathrm{Encke}}=\left(\frac{a}{a_{\mathrm{E}}}\right)^{\frac{3}{2}}t_{\mathrm{E}}=3.30\ \mathrm{year}=1.04\times10^{8}\ \mathrm{s}$.	0.6

1.6a	For Earth around its rotation axis: Angular velocity $\omega_{\mathrm{E}}=\frac{2\pi}{24\ \mathrm{h}}=7.27\times10^{-5}\ \mathrm{s^{-1}}$. Moment of inertia $I_{\mathrm{E}}=0.83\frac{2}{5}m_{\mathrm{E}}R_{\mathrm{E}}^2=8.07\times10^{37}\ \mathrm{kg\,m^2}$. Angular momentum $L_{\mathrm{E}}=I_{\mathrm{E}}\omega_{\mathrm{E}}=5.87\times10^{33}\ \mathrm{kg\,m^2s^{-1}}$. Astroid $m_{\mathrm{ast}}=\frac{4\pi}{3}R_{\mathrm{ast}}^3\rho_{\mathrm{ast}}=1.57\times10^{15}\ \mathrm{kg}$ and angular momentum $L_{\mathrm{ast}}=m_{\mathrm{ast}}v_{\mathrm{ast}}R_{\mathrm{E}}=2.51\times10^{26}\ \mathrm{kg\,m^2s^{-1}}$. L_{ast} is perpendicular to L_{E}, so by conservation angular momentum: $\tan(\Delta\theta)=\;L_{\mathrm{ast}}/L_{\mathrm{E}}=4.27\times10^{-8}$. The axis tilt $\Delta\theta=4.27\times10^{-8}$ rad (so the north pole move $R_{\mathrm{E}}\,\Delta\theta=0.27$ m).	0.7
1.6b	At vertical impact $\Delta L_{\mathrm{E}}=0$ so $\Delta(I_{\mathrm{E}}\omega_{\mathrm{E}})=0$. Thus $\Delta\omega_{\mathrm{E}}=-\omega_{\mathrm{E}}(\Delta I_{\mathrm{E}})/I_{\mathrm{E}}$, and since $\Delta I_{\mathrm{E}}/I_{\mathrm{E}}=m_{\mathrm{ast}}R_{\mathrm{E}}^2/I_{\mathrm{E}}=7.9\times10^{-10}$ we obtain $\Delta\omega_{\mathrm{E}}=-5.76\times10^{-14}\ \mathrm{s^{-1}}$. The change in rotation period is $\Delta T_{\mathrm{E}}=2\pi\left(\frac{1}{\omega_{\mathrm{E}}+\Delta\omega_{\mathrm{E}}}-\frac{1}{\omega_{\mathrm{E}}}\right)\approx-2\pi\frac{\Delta\omega_{\mathrm{E}}}{\omega_{\mathrm{E}}^2}=6.84\times10^{-5}\ \mathrm{s}$.	0.7
1.6c	At tangential impact L_{ast} is parallel to L_{E} so $L_{\mathrm{E}}+L_{\mathrm{ast}}=(\,I_{\mathrm{E}}+\Delta I_{\mathrm{E}})(\omega_{\mathrm{E}}+\Delta\omega_{\mathrm{E}})$ and thus $\Delta T_{\mathrm{E}}=2\pi\left(\frac{1}{\omega_{\mathrm{E}}+\Delta\omega_{\mathrm{E}}}-\frac{1}{\omega_{\mathrm{E}}}\right)=2\pi\left(\frac{I_{\mathrm{E}}+\Delta I_{\mathrm{E}}}{L_{\mathrm{E}}+L_{\mathrm{ast}}}-\frac{1}{\omega_{\mathrm{E}}}\right)=-3.62\times10^{-3}\ \mathrm{s}$.	0.7

1.7a	Minimum impact speed is the escape velocity from Earth: $v_{\mathrm{imp}}^{\mathrm{min}} = \sqrt{\frac{2Gm_E}{R_E}} = 11.2\ \mathrm{km/s}$	0.5
1.7b	Maximum impact speed $v_{\mathrm{imp}}^{\mathrm{max}}$ arises from three contributions: (I) The velocity v_{b} of the body at distance a_{E} (Earth orbit radius) from the Sun, $v_{\mathrm{b}} = \sqrt{\frac{2Gm_S}{a_E}} = 42.1\ \mathrm{km/s}$. (II) The orbital velocity of the Earth, $v_{\mathrm{E}} = \frac{2\pi a_E}{1\ \mathrm{year}} = 29.8\ \mathrm{km/s}$. (III) Gravitational attraction from the Earth and kinetic energy seen from the Earth: $\frac{1}{2}(v_{\mathrm{b}} + v_{\mathrm{E}})^2 = -\frac{Gm_E}{R_E} + \frac{1}{2}\left(v_{\mathrm{imp}}^{\mathrm{max}}\right)^2$. In conclusion: $v_{\mathrm{imp}}^{\mathrm{max}} = \sqrt{(v_{\mathrm{b}} + v_{\mathrm{E}})^2 + \frac{2Gm_E}{R_E}} = 72.8\ \mathrm{km/s}$.	1.2

	Total	**9.0**