Question Number	Scheme	Marks
4(i)	$\dfrac{\mathrm{d}V}{\mathrm{d}t} = 70\pi$	B1
	$\dfrac{\mathrm{d}V}{\mathrm{d}r} = 4\pi r^2$	B1
	$\dfrac{\mathrm{d}V}{\mathrm{d}t} = \dfrac{\mathrm{d}V}{\mathrm{d}r} \times \dfrac{\mathrm{d}r}{\mathrm{d}t} \Rightarrow 70\pi = 4\pi \times 5^2 \times \dfrac{\mathrm{d}r}{\mathrm{d}t}$ or e.g. $\dfrac{\mathrm{d}r}{\mathrm{d}t} = \dfrac{\mathrm{d}V}{\mathrm{d}t} \times \dfrac{\mathrm{d}r}{\mathrm{d}V} \Rightarrow \dfrac{\mathrm{d}r}{\mathrm{d}t} = 70\pi \times \dfrac{1}{4\pi \times 5^2}$	M1
	$\left(\dfrac{\mathrm{d}r}{\mathrm{d}t}\right) = 0.7$ (cm s^{-1}) oe e.g. $\dfrac{7}{10}$	A1
		(4)
	Alternative:	
	$V = 70\pi t$	B1
	$\dfrac{4}{3}\pi r^3 = 70\pi t$	B1
	$\dfrac{4}{3}\pi r^3 = 70\pi t \Rightarrow 4\pi r^2 \dfrac{\mathrm{d}r}{\mathrm{d}t} = 70\pi \Rightarrow 100\dfrac{\mathrm{d}r}{\mathrm{d}t} = 70$ or $\dfrac{4}{3}\pi r^3 = 70\pi t \Rightarrow r^3 = \dfrac{105}{2}t \Rightarrow r = \left(\dfrac{105}{2}t\right)^{\frac{1}{3}}$ $\left(\dfrac{4}{3}\pi r^3 = 70\pi t \Rightarrow \dfrac{500}{3}t = 70 \Rightarrow t = \dfrac{50}{21}\right)$ $\Rightarrow \dfrac{\mathrm{d}r}{\mathrm{d}t} = \dfrac{1}{3}\left(\dfrac{105}{2}\right)^{\frac{1}{3}} t^{-\frac{2}{3}} = \dfrac{1}{3}\left(\dfrac{105}{2}\right)^{\frac{1}{3}}\left(\dfrac{50}{21}\right)^{-\frac{2}{3}}$	M1
	$\left(\dfrac{\mathrm{d}r}{\mathrm{d}t}\right) = 0.7$ (cm s^{-1}) oe e.g. $\dfrac{7}{10}$	A1

Notes:

B1: States or uses $\dfrac{\mathrm{d}V}{\mathrm{d}t} = 70\pi$ oe e.g. $\dfrac{\mathrm{d}t}{\mathrm{d}V} = \dfrac{1}{70\pi}$

B1: States or uses $\dfrac{\mathrm{d}V}{\mathrm{d}r} = 4\pi r^2$ oe e.g. $\dfrac{\mathrm{d}r}{\mathrm{d}V} = \dfrac{1}{4\pi r^2}$ which may be seen as $\dfrac{\mathrm{d}V}{\mathrm{d}r} = 100\pi$ or $\dfrac{\mathrm{d}r}{\mathrm{d}V} = \dfrac{1}{100\pi}$ if $r = 5$ has been substituted.

M1: Attempts to use $\dfrac{\mathrm{d}V}{\mathrm{d}t} = \dfrac{\mathrm{d}V}{\mathrm{d}r} \times \dfrac{\mathrm{d}r}{\mathrm{d}t}$ or equivalent with $r = 5$ and their $\dfrac{\mathrm{d}V}{\mathrm{d}r}$ and $\dfrac{\mathrm{d}V}{\mathrm{d}t}$ correctly placed e.g. $70\pi = 4\pi \times 5^2 \times \dfrac{\mathrm{d}r}{\mathrm{d}t}$ or e.g. $\dfrac{\mathrm{d}r}{\mathrm{d}t} = \dfrac{\mathrm{d}V}{\mathrm{d}t} \times \dfrac{\mathrm{d}r}{\mathrm{d}V} = \dfrac{70\pi}{4\pi(5)^2}$

A1: $\left(\dfrac{\mathrm{d}r}{\mathrm{d}t}\right) = 0.7$ oe (Units are not required but if any are given they must be correct)

(i) Alternative:

B1: States or uses $V = 70\pi t$

B1: States or uses $\frac{4}{3}\pi r^3 = 70\pi t$

M1: For either:

- Differentiating $\frac{4}{3}\pi r^3 = 70\pi t$ to obtain $...r^2 \frac{\mathrm{d}r}{\mathrm{d}t} = ...$ and substituting $r = 5$ **or**
- Making r the subject from $\frac{4}{3}\pi r^3 = 70\pi t$ to obtain $r = ...t^{\frac{1}{3}}$ and then differentiating to obtain $\frac{\mathrm{d}r}{\mathrm{d}t} = ...t^{-\frac{2}{3}}$ and then substituting t obtained from $\frac{4}{3}\pi(5)^3 = 70\pi t$

A1: $\frac{\mathrm{d}r}{\mathrm{d}t} = 0.7$ oe (Units are not required but if any are given they must be correct)

(ii)	$\frac{\mathrm{d}h}{\mathrm{d}t} = \frac{k}{h^3} \Rightarrow \int h^3 \,\mathrm{d}h = \int k \,\mathrm{d}t \Rightarrow \frac{1}{4}h^4 = kt + c$	M1A1
	$t = 0,\ h = 4 \Rightarrow \frac{1}{4} \times 4^4 = 0 + c \Rightarrow c = 64$	M1
	$t = 5,\ h = 6 \Rightarrow \frac{1}{4} \times 6^4 = k \times 5 + 64 \Rightarrow k = (52)$	dM1
	$h = 10 \Rightarrow \frac{1}{4}(10)^4 = 52T + 64 \Rightarrow T = ...$	dddM1
	46.8 (hours) or exact e.g. $\frac{609}{13}, \frac{9744}{208}$	A1
		(6)
		(10 marks)

Notes:

M1: Separates variables and integrates both sides to obtain $...h^4 = kt(+c)$ or equivalent.

There is no need for a constant of integration for this mark.

A1: $\frac{1}{4}h^4 = kt(+c)$ or equivalent, with or without a constant of integration.

M1: Requires a constant of integration and using $t = 0,\ h = 4$ to find their c.

Condone poor integration and poor attempts to rearrange their equation for this mark.

dM1: Uses $t = 5,\ h = 6$ to find k.

It is dependent upon the **previous** mark and having two correctly placed constants.

Condone poor integration and poor attempts to rearrange their equation for this mark.

dddM1: Dependent upon **all three previous** M's.

It is for substituting $h = 10$ into their equation and finding T (or t)

A1: Awrt 46.8 or exact e.g. $\frac{609}{13}, \frac{9744}{208}$. Allow better accuracy e.g. 46.85.

It does not have to be referenced as "T" so just look for the correct value.

Units are not required but if any are given they must be correct.

See next pages for alternatives to (ii)