Question		Answer	Marks	AO	Guidance
5	(a)	$r_{max} = 10\,(\text{m})$	B1 [1]	3.4	cao of 10 – units not required. Allow $r \to 10$ (or in words e.g. 'r tends to 10'), but **not** for 9.99… (but allow for 10 following on from 9.99….).
	(b)	$10\left(1-e^{-0.3t}\right) = 6 \Rightarrow e^{-0.3t} = 0.4$	M1	3.4	Set $r = 6$ and make $e^{-0.3t}$ the subject – correct order of operations but allow sign errors.
		$-0.3t = \ln(0.4)$	M1	2.1	Correctly taking ln of both sides to obtain an equation of the form $-0.3t = \ln(k)$ – must be from an equation of the form $e^{-0.3t} = k$ where $k > 0$.
		$t = -\dfrac{\ln(0.4)}{0.3} = 3.05$	A1 [3]	1.1	awrt 3.05 (for reference: 3.0543024…). Do **not** accept an exact answer only (due to the context of time).

Question		Answer	Marks	AO	Guidance
	(c)	$\frac{dr}{dt} = 3e^{-0.3t}$	M1*	1.1	$\left(\frac{dr}{dt} =\right) k_1 e^{-0.3t}$ where $k_1 \neq 0, \pm 10$.
		$\frac{dA}{dr} = 2\pi r$ or $\left.\frac{dA}{dr}\right\|_{r=6} = 12\pi$	B1*	3.1a	For either $2\pi r$ or 12π (or 37.69…) seen. However, stating that $\frac{dA}{dt} = 2\pi r$ or $\frac{dA}{dt} = 12\pi$ is **B0**.
		$\frac{dA}{dt} = \frac{dA}{dr} \times \frac{dr}{dt} = 2\pi(6) \times 3e^{-0.3(3.05\ldots)}$	M1dep*	2.1	Correct use of chain rule to find numerical expression for $\frac{dA}{dt}$ – must be using $r = 6$ and their positive value of t from part **(b)** oe e.g. substituting their $e^{-0.3t} = 0.4$ from part **(b)**, **so** if correct, may see $12\pi \times 3 \times 0.4$. The correct answer implies this mark.
		45 ($m^2\ hr^{-1}$)	A1	1.1	awrt 45 (for ref: 45.238934…), allow exact answer of $\frac{72}{5}\pi$.
		Alternative Method			
		$A = \pi r^2 = \pi \times 10^2 \times \left(1 - e^{-0.3t}\right)^2$	B1*		Correct expression/equation for A in terms of t.
		$\frac{dA}{dt} = 2 \times 0.3e^{-0.3t} \times 10^2 \times \pi\left(1 - e^{-0.3t}\right)$	M1*		For $\frac{dA}{dt} = k_2 e^{-0.3t}\left(1 - e^{-0.3t}\right)$ where $k_2 \neq 0, \pm 100\pi$.
		$\frac{dA}{dt} = 2 \times 0.3e^{-0.3\times 3.05\ldots} \times 10^2 \times \pi\left(1 - e^{-0.3\times 3.05\ldots}\right)$	M1dep*		Substituting their positive value of t from part **(b)** oe e.g. substituting their $e^{-0.3t} = 0.4$ from part **(b)**, therefore if correct, may see $\frac{dA}{dt} = 2 \times 0.3 \times 0.4 \times 10^2 \times \pi(1 - 0.4)$. The correct answer implies this mark.
		45 ($m^2\ hr^{-1}$)	A1		awrt 45 (for ref: 45.238934…), allow exact answer of $\frac{72}{5}\pi$.
			[4]		**If correct answer is found from BC (so no differentiation seen) then 2 marks max. e.g. in the Alternative Method B1 for A in terms of t and then SC B1 for the 45 (oe).**