Question	Scheme	Marks	AOs
7(a)	$\{H=\}\ 0.6\mathrm{e}^{-0.2t}\ \{+c\}$	M1	1.1b
	$t=0, H=1.5 \Rightarrow 1.5="0.6"+c$ $\Rightarrow c=0.9$	dM1	3.4
	$\Rightarrow H=0.6\mathrm{e}^{-0.2t}+0.9$	A1	2.1
		(3)	
(b)	$1.2=0.6\mathrm{e}^{-0.2t}+0.9 \Rightarrow 0.6\mathrm{e}^{-0.2t}=0.3$	M1	3.4
	$\mathrm{e}^{-0.2t}=\frac{1}{2}$ $\Rightarrow t=-5\ln\left(\frac{1}{2}\right)$	dM1	1.1b
	$\{t=\}$ 3 hours 28 minutes	A1	3.2a
		(3)	
(c)	{As t gets large $H\to$} 0.9	M1	3.1b
	0.9 m or 90 cm	A1ft	2.2b
		(2)	
			(8 marks)

Notes

(a)

M1: Attempts integration to achieve $\{H=\}\ k\,\mathrm{e}^{-0.2t}\ \{+c\}$ with k a numerical constant $\neq -0.12$

Note that we will condone $k = (-0.2)(-0.12)$ {$= 0.024$}

If they divide by –0.12 first before integrating they need $aH=b\mathrm{e}^{-0.2t}\ \{+c\}$ with a and b numerical and $b\neq 1$. Condone a spurious integral symbol remaining after integration.

dM1: Uses $t=0, H=1.5$ and a model of the form $H=k\,\mathrm{e}^{-0.2t}+c$ (or $aH=b\mathrm{e}^{-0.2t}+c$) to find the value of the constant c. They cannot just "make up" a value for k.

Do not be concerned with their processing to find c but they cannot just state B (or c) is 0.

For reference if they divide by –0.12 first they should reach $-\frac{25}{3}H=-5\mathrm{e}^{-0.2t}-7.5$ o.e.

A1: Correct complete equation in the required form: $H=0.6\mathrm{e}^{-0.2t}+0.9$ with the H = present.

May be awarded if seen at the start of (b) but not in (c). Condone $-\frac{1}{5}$ in place of –0.2

Finding correct values for A and B is insufficient for this mark.

Allow exact equivalents but they must be in the required form, e.g. $H=\frac{6}{10}\mathrm{e}^{-0.2t}+\frac{9}{10}$

A minimally acceptable answer is $\{H=\}\ 0.6\mathrm{e}^{-0.2t}+c \to H=0.6\mathrm{e}^{-0.2t}+0.9$ score M1dM1A1.

Note: sight of differentiating the given form to e.g. $\frac{\mathrm{d}H}{\mathrm{d}t}=-0.2A\mathrm{e}^{-0.2t}$ in their working without clear evidence of integration of the original differential equation should be marked using the special case below.

SC: For candidates starting with the given answer $H=A\mathrm{e}^{-0.2t}+B$ it is possible to use $\frac{\mathrm{d}H}{\mathrm{d}t}=-0.2A\mathrm{e}^{-0.2t}=-0.12\mathrm{e}^{-0.2t}$ to deduce that $A=0.6$. This can be awarded SC M1dM0A0

If they go on to find B as in the main scheme then this can be awarded SC M1dM1A0

Answer with no working scores 110.

Note: If the special case is applied they may go on to achieve the rest of the marks in (b) and (c).

(b) Note: *A* and *B* must be numbers but may be "made up" if they did not have an answer to (a).

M1: Uses $H = 1.2$ in a model of the form $H = Ae^{-0.2t} + B,\ B \neq 0$ and rearranges to make $Ae^{\pm 0.2t}$ or $e^{\pm 0.2t}$ the subject. Condone slips in rearranging, e.g. dividing the LHS by 0.9 instead of subtracting 0.9. Rearranging first before substituting is acceptable but they must get to $Ae^{\pm 0.2t}$ or $e^{\pm 0.2t}$ as the subject.

dM1: Correct use of ln to make *t* the subject. Requires $A > 0,\ 0 < B < 1.2$ **and** $e^{\pm 0.2t} = \lambda > 0$
If they had a negative value for *A* in part (a) they cannot just make it positive at this stage.
Any of $5\ln 2$ or $-5\ln\frac{1}{2}$ or awrt 3.46 or awrt 3.47 following a correct equation will imply M1dM1.
If they do not show their method for an incorrect $H = Ae^{-0.2t} + B$ with $A > 0,\ 0 < B < 1.2$ you may need to check their value for $t > 0$ as it may imply M1dM1.

A1: Correct time in hours and minutes $\{t =\}\ 3\text{hours } 28\text{minutes}$, but condone e.g. 3h 28m
Must come from correct values of *A* and *B* in (a).

Note: If their $B = 0$ then they should end up with $t = -3.46\ldots$ however, they did not score the first M1. They cannot "recover" this by making it positive and finding $t = 3\text{hours } 28\text{minutes}$.

(c) Note that 0.9 or 0.9m must come from a correct value of *B* in (a) to score any marks.

M1: Identifies the requirement to establish the limit as *t* tends to infinity.
It can be implied by stating that $H = Ae^{-0.2t} + B \to B$ or $\left(\lim_{t\to\infty}\left[0.6e^{-0.2t} + 0.9\right]\right) = 0.9$
Stating "*B*" on its own will score this mark.
Substituting a large value is M0 unless it leads to their value for *B* at which point the A1 is available as well.

A1ft: Correct height including units. Follow through on their value of *B* where $0 < B < 1.2$
Correct ft height including units implies M1A1, while e.g. 0.9 (no units) would imply M1A0.
Evidence of an incorrect method such as $1.5 - 0.6e^{-0.2(0)} = 0.9\,\text{m}$ scores M0A0.

Misreading as $\frac{dH}{dt} = -0.12e^{0.2t}$ can score a maximum (a) 110 (b) 100 (c) 10.