(c)	Sets $\dfrac{(15+\mathrm{e}^{0.8t})\times 96\mathrm{e}^{0.6t}-160\mathrm{e}^{0.6t}\times 0.8\mathrm{e}^{0.8t}}{(15+\mathrm{e}^{0.8t})^2}=0$ $\Rightarrow (15+\mathrm{e}^{0.8t})\times 96\mathrm{e}^{0.6t}-160\mathrm{e}^{0.6t}\times 0.8\mathrm{e}^{0.8t}=0$ $\Rightarrow 1440\mathrm{e}^{0.6t}=32\mathrm{e}^{1.4t}$ or e.g. $\mathrm{e}^{0.8t}=45$ oe **or** $-160\mathrm{e}^{0.6t}(15+\mathrm{e}^{0.8t})^{-2}\times 0.8\mathrm{e}^{0.8t}+(15+\mathrm{e}^{0.8t})^{-1}\times 128\mathrm{e}^{0.6t}=0$ $\Rightarrow 1440\mathrm{e}^{0.6t}=32\mathrm{e}^{1.4t}$ or e.g. $\mathrm{e}^{0.8t}=45$ oe	M1A1
	$\Rightarrow T=\dfrac{\ln 45}{0.8}=4.76$	**d**M1A1
		(4)
		(9 marks)

Notes

Allow recovery here if signs are reversed in their derivative.

May work in *T* and/or *t*.

M1: Sets the numerator of their quotient rule attempt = 0 or sets their product rule attempt = 0 and obtains $p\mathrm{e}^{0.8t}=q$ or $A\mathrm{e}^{0.6t}=B\mathrm{e}^{1.4t}$ or equivalent.
The denominator of their quotient rule (correct or incorrect) can be ignored in part (c).

A1: $1440\mathrm{e}^{0.6t}=32\mathrm{e}^{1.4t}$ or $\mathrm{e}^{0.8t}=45$ or an equivalent correct equation.
Must follow correct work but allow this mark if the only error is reversed signs in their derivative.

dM1: Having set $\dfrac{\mathrm{d}P}{\mathrm{d}t}=0$ and obtained either $A\mathrm{e}^{\pm kt}=B$ (k may be incorrect) or $C\mathrm{e}^{\pm\alpha t}=D\mathrm{e}^{\pm\beta t}$ where $k,\alpha,\beta\neq 0$ it is for the correct order of operations including taking ln's leading to $t=\ldots$
May be implied by their value of t.
It cannot be awarded for impossible equations e.g. $\mathrm{e}^{0.8t}=-45$
Depends on the first method mark.

A1: $T=\dfrac{\ln 45}{0.8}$ or equivalent or awrt 4.76
Must follow correct work but allow this mark if the only error is reversed signs in their derivative.

Question Number	Scheme	Marks
8(a)	$R = \sqrt{109}$	B1
	$\tan\alpha = \frac{3}{10} \Rightarrow \alpha = \text{awrt}\, 16.70°$	M1A1
		(3)
(b)(i)	Max height = 12+ ' $\sqrt{109}$ '= awrt 22.44 (m)	B1ft
(ii)	Occurs when $30t + '16.70' = 180 \Rightarrow t = 5.44$	M1A1
		(3)

Notes

(a)

B1: $R = \sqrt{109}$. Apply isw after this is seen e.g. if they convert to a decimal.
Do not allow $R = \pm\sqrt{109}$.

M1: Attempts to find α. Look for $\tan\alpha = \pm\frac{3}{10} \Rightarrow \alpha = ...$ but condone $\tan\alpha = \pm\frac{10}{3} \Rightarrow \alpha = ...$

or if R is used allow $\sin\alpha = \pm\frac{3}{R} \Rightarrow \alpha = ...$ or $\cos\alpha = \pm\frac{10}{R} \Rightarrow \alpha = ...$

A1: $\alpha = \text{awrt}\, 16.70°$ but condone $\alpha = 16.7°$
It is **not** for awrt 16.7 e.g. 16.67 scores A0
An answer of $\alpha = \text{awrt}\, 0.29$ radians scores A0

(b)(i)

B1ft: For awrt 22.44 (m) or $12 + \sqrt{109}$ following a correct value for R but ft on their R value so allow for 12 + their R in exact form or for 12 + their R as awrt 2dp (you may need to check).
Units are **not** required but if any are present they should be correct.

(b)(ii)

M1: Attempts to solve $30t + '16.70' = 180$ to obtain a value for t.
If radians were used in part (a) then allow an attempt to solve $30t + '0.29' = \pi$
(which leads to $t = 0.095\ldots$) but do **not** allow mixing of degrees and radians e.g.
$30t + '0.29' = 180 \Rightarrow t = ...$
Allow methods that use e.g. $x = 30t \Rightarrow x + '16.70' = 180$ etc. provided they subsequently replace x with $30t$ and find t.
May be implied by their value for t.

A1: awrt 5.44 only.
If multiple solutions are found then awrt 5.44 must clearly be identified as their chosen solution.

(c)	$18 = 12 - \sqrt{109}\cos(30t + 16.70) \Rightarrow \cos(30t + 16.70) = -\dfrac{6}{\sqrt{109}}$ $(-0.57..)$	M1A1
	$\Rightarrow 30t + 16.70 = \arccos\left(-\dfrac{6}{\sqrt{109}}\right)(= 125.078...^\circ) \Rightarrow t = ..$	**d**M1
	$t =$ awrt 3.61(2dp)	A1
		(4)

Notes

M1: Uses $H = 18$ in their answer to part (a) and proceeds to $\cos(30t + '16.70') = k$ where $|k| < 1$

Allow this mark for $18 = 12 - "\sqrt{109}"\cos(30t + "16.70")$ leading to $\cos(30t + '16.70') = k$ where $|k| < 1$

A1: $\cos(30t + '16.70') = -\dfrac{6}{\sqrt{109}}$ or awrt $-0.57...$ following through on their α

May be implied by $30t + '16.70' =$ awrt 125° or awrt 2.2 radians.

dM1: Correct order of operations to find a **positive** value for t from their **negative** value for k.

The order of operations must be correct from their $\cos(30t + '16.70') = k$ $(-1 < k < 0)$ and the value chosen must be in the second quadrant.

Condone use of radians if consistent with their value of α e.g.

$18 = 12 - \sqrt{109}\cos(30t + "0.29") \Rightarrow \cos(30t + "0.29") = -\dfrac{6}{\sqrt{109}}$ $(-0.57..)$

$\Rightarrow 30t + "0.29" = \arccos\left(-\dfrac{6}{\sqrt{109}}\right) = 0.2183... \Rightarrow t = ..(0.0631\ldots)$

but do not allow mixing of degrees and radians.

Depends on the first method mark.

A1: awrt 3.61 and no other values following the award of M1, A1 dM1

Allow methods that use e.g. $x = 30t$ etc. provided they subsequently replace x with $30t$ and find t.

For reference:

Work and marks for a candidate working entirely in radians in (a), (b) and (c):

(a) $R = \sqrt{109}$, $\alpha = 0.29$ B1M1A0

(b)(i) 12+ '$\sqrt{109}$'= awrt 22.44 m B1

(b)(ii) $30t + 0.29 = \pi \Rightarrow t = 0.095...$ M1A0

(c) $18 = 12 - \sqrt{109}\cos(30t + 0.29) \Rightarrow \cos(30t + 0.29) = -\dfrac{6}{\sqrt{109}}$ $(-0.57..)$ M1A1

$\Rightarrow 30t + 0.29 = \arccos\left(-\dfrac{6}{\sqrt{109}}\right)(= 2.183...) \Rightarrow t = ..$ M1

$\Rightarrow t = 0.063...$ A0

(d)	$30t = 360 \Rightarrow t = ..$ or $30t = 720 \Rightarrow t = ..$	M1
	24 minutes	A1
		(2)
Notes		
M1: Attempts to solve either $30t = 360$ or $30t = 720$ to find t or else states 12 or 24		
A1: 24 minutes. Requires minutes or e.g. "mins", "min", "m".		
		(12 marks)