Question Number	Scheme	Marks
6a	$\frac{k}{2k-15}=\frac{k+4}{k}\Rightarrow k^2=2k^2+8k-15k-60\Rightarrow k^2-7k-60=0$ *	M1A1*
		(2)
b	$k=12$	B1
	$\Rightarrow \frac{"12"}{2\times"12"-15}\ \left(=\frac{4}{3}\right)$	M1
	e.g. $("12"+4)\times\frac{4}{3}=...$ or $(2\times"12"-15)\times\left("\frac{4}{3}"\right)^3=...$	M1
	$=21300$	A1
		(4)
c	e.g. $\frac{9\left(1-\left(\frac{4}{3}\right)^N\right)}{1-\frac{4}{3}}>3000\Rightarrow\left(\frac{4}{3}\right)^N>\frac{1009}{9}$	M1
	$\log\left(\frac{4}{3}\right)^N>\log\left(\frac{1009}{9}\right)\Rightarrow N>\frac{\log\left(\frac{1009}{9}\right)}{\log\left(\frac{4}{3}\right)}$	dM1
	$N>16.405...\Rightarrow N=17$	A1
		(3)
		(9 marks)

(a)

M1 Forms a correct equation linking the three terms and attempts to rearrange to the given quadratic (it cannot be awarded for just proceeding in one step from the starting equation to the given answer and usually will involve attempting to multiply out brackets or dealing with any fractions). Must proceed as far as a quadratic with terms collected.
Condone slips in their rearrangement and invisible brackets.
Possible starting equations will involve using the *n*th term formula or the sum of a geometric series. The ones below are not exhaustive.

$\frac{k}{2k-15}=\frac{k+4}{k}$ or $k^2=(k+4)(2k-15)$ $\left((u_2)^2=u_1\times u_3\right)$ or $(2k-15)\left(\frac{k+4}{k}\right)=k$ or

$k\left(\frac{k}{2k-15}\right)=k+4$ or $2k-15+k+k+4=\frac{(2k-15)\left(1-\left(\frac{k}{2k-15}\right)^3\right)}{1-\frac{k}{2k-15}}$ (sum of 3 terms)

A1* Rearranges to achieve $k^2-7k-60=0$ with no errors seen including brackets. There must be at least some intermediate working (e.g. brackets multiplied out or multiplying to remove any fractions) between their starting equation and the given answer.

(b) **Note a candidate who uses *k* as *r* can only score maximum B1 in (b) and no marks in (c)**

B1 12 (ignore -5) seen or used in (b) (may be implied by the value of the second term)

M1 Substitutes their 12 (must be positive) into the expressions for two of the terms and attempts to find a value for *r*. Condone arithmetical slips but they the division the correct way round.

M1 Attempts to find the 4th term using their positive *k* and their positive *r* eg $("12"+4)\times"\frac{4}{3}"=...$

(may be implied by awrt 21.3). Alternatively, they may find the first term *a* and use this with their *r* to find the 4th term. Condone slips in finding *a*

Condone *r* to be rounded from their earlier work and condone missing brackets but not incorrectly placed brackets.

A1 21300 or 21330 or 21333 only or their equivalences e.g. 21.3 thousand

(c) **Typically, candidates will work in base 10, but other bases such as their *r* is acceptable**

M1 Uses their $a="9"$ or $a="9000"$ and their positive $r="\frac{4}{3}"$ in the sum of a geometric formula $\Rightarrow$

$\frac{"9"\left(1-\left("\frac{4}{3}"\right)^N\right)}{1-"\frac{4}{3}"}$....3... (may be = or any inequality in between) and proceeds to $A\left("\frac{4}{3}"\right)^N ...B$

(condone $A\times B$ to be negative), where *A* could be 1 and *B* could be unsimplified. Do not be concerned with the number of 0s after the 3.

Do not be concerned by the mechanics of their rearrangement and may be implied by further work if logarithms are used correctly. Condone *r* to be rounded from their earlier work and condone missing brackets but not incorrectly placed brackets.

dM1 Attempts to find *N* using logarithms correctly. Do not be concerned with the use of equals or the direction of any inequality used for this mark. May be implied by a correct expression (not a value) for *N*. It is dependent on the previous method mark.

This mark can only be scored if $A\times B>0$ for their $A\left("\frac{4}{3}"\right)^N ...B$

A1 17 cso (if an incorrect inequality sign is used at some point in their working then withhold this final mark) This mark can only be scored provided there are **no arithmetical errors** and **correct log work** is seen as part of their solution. Do not withhold the mark for invisible brackets around their $\left(\frac{4}{3}\right)^N$. Condone if *r* is rounded from $\frac{4}{3}$. If a value for *N* is found before deducing $N=17$ then it must be 16.4 or better. 17 with no working seen is 0 marks.

Note e.g. $N>\log_{\frac{4}{3}}\left(\frac{991}{9}\right)\Rightarrow N=17$ is A0 (arithmetical slip combining $1+\frac{1000}{9}$)

$\frac{9\left(1-\left(\frac{4}{3}\right)^N\right)}{1-\frac{4}{3}}>3000\Rightarrow\left(\frac{4}{3}\right)^N>\frac{1009}{9}\Rightarrow N=17$ scores M1dM0A0 (insufficient working)

$\frac{9\left(1-\left(\frac{4}{3}\right)^N\right)}{1-\frac{4}{3}}<3000\Rightarrow N<\frac{\log\left(\frac{1009}{9}\right)}{\log\left(\frac{4}{3}\right)}\Rightarrow N=17$ scores M1dM1A0 (inequality sign errors)

$\frac{9000\left(1-\left(\frac{4}{3}\right)^N\right)}{1-\frac{4}{3}}>3000000\Rightarrow N>\log_{\frac{4}{3}}\left(\frac{1009}{9}\right)\Rightarrow N=17$ scores M1dM1A1 (implied M marks)

Note: Methods relying on trial and improvement, or the equation solver score maximum M1dM0A0

Question Number	Scheme	Marks
7a	$H = t^{\frac{1}{2}} + \frac{3t^{\frac{3}{2}}}{10} - \frac{t^{\frac{5}{2}}}{20} + 17 \Rightarrow \left(\frac{\mathrm{d}H}{\mathrm{d}t} =\right) \frac{1}{2}t^{-\frac{1}{2}} + \frac{9}{20}t^{\frac{1}{2}} - \frac{1}{8}t^{\frac{3}{2}}$	M1A1A1
	e.g. $\frac{1}{2}t^{-\frac{1}{2}} + \frac{9}{20}t^{\frac{1}{2}} - \frac{1}{8}t^{\frac{3}{2}} = 0 \Rightarrow \frac{1}{2} + \frac{9}{20}t - \frac{1}{8}t^{2} = 0 \ldots \Rightarrow 5\alpha^2 - 18\alpha - 20 = 0$ *	dM1A1*
		(5)
b	$\alpha = \frac{9+\sqrt{181}}{5} = \text{awrt } 4.491$	B1
		(1)
c	$\left(\frac{\mathrm{d}^2H}{\mathrm{d}t^2} =\right) -\frac{1}{4}t^{-\frac{3}{2}} + \frac{9}{40}t^{-\frac{1}{2}} - \frac{3}{16}t^{\frac{1}{2}} \Rightarrow -\frac{("4.49")^{-\frac{3}{2}}}{4} + \frac{9("4.49")^{-\frac{1}{2}}}{40} - \frac{3("4.49")^{\frac{1}{2}}}{16}$	M1
	$\frac{\mathrm{d}^2H}{\mathrm{d}t^2} = (-0.3\ldots) < 0 \Rightarrow \max$ *	A1*
		(2)
		(8 marks)

(a) **If they change *t* to α before differentiating then score maximum M1A1A0dM1A0**

M1 Multiplies out and attempts to differentiate. Award for one correct index from correct working (may be implied if they multiply out and differentiate at the same time) $t^{\frac{3}{2}}$ or $t^{\frac{1}{2}}$ or $t^{-\frac{1}{2}}$ (condone if these are $\alpha^{\frac{3}{2}}$ or $\alpha^{\frac{1}{2}}$ or $\alpha^{-\frac{1}{2}}$ or any other variable) The indices do not need to be processed for this mark.
e.g. $t^{\frac{5}{2}-1}$
Alternatively, they may attempt the product rule so look for a correct general expression such as $\left(\frac{\mathrm{d}H}{\mathrm{d}t} =\right) \ldots t^{-\frac{1}{2}}(20+6t-t^2) + \ldots t^{\frac{1}{2}}(A+Bt)$ (condone if in terms of α or another variable instead)

A1 One of $\frac{1}{2}t^{-\frac{1}{2}}$, $\frac{9}{20}t^{\frac{1}{2}}$, $-\frac{1}{8}t^{\frac{3}{2}}$ (simplified or unsimplified) via the main scheme
If they differentiate using the product rule then this mark can only be awarded for one of $\frac{1}{40}t^{-\frac{1}{2}}(20+6t-t^2) + \ldots t^{\frac{1}{2}}(A+Bt)$ or $\ldots t^{-\frac{1}{2}}(20+6t-t^2) + \frac{1}{20}t^{\frac{1}{2}}(6-2t)$ (unsimplified).
In both cases the indices must be processed. Condone if in terms of α

A1 $\left(\frac{\mathrm{d}H}{\mathrm{d}t} =\right) \frac{1}{2}t^{-\frac{1}{2}} + \frac{9}{20}t^{\frac{1}{2}} - \frac{1}{8}t^{\frac{3}{2}}$ or equivalent e.g. $\left(\frac{\mathrm{d}H}{\mathrm{d}t} =\right) \frac{1}{40}t^{-\frac{1}{2}}\left(20+18t-5t^2\right)$ which may be unsimplified. Also allow
e.g. $\left(\frac{\mathrm{d}H}{\mathrm{d}t} =\right) \frac{1}{40}t^{-\frac{1}{2}}(20+6t-t^2) + \frac{1}{20}t^{\frac{1}{2}}(6-2t)$ (via the product rule)

dM1 Sets their derivative of the form $\ldots t^{-\frac{1}{2}} \pm \ldots t^{\frac{1}{2}} \pm \ldots t^{\frac{3}{2}} = 0$ (may be implied) and proceeds via a correct method to a 3TQ in *t* or α (or any other variable) where the powers and the coefficients of the terms are integers. Condone sign slips only. It is dependent on the previous method mark.
Proceeding directly to the given answer is M0, unless they state how they have proceeded from the derivative directly to the given answer e.g. set $t = \alpha$ **and** $\times -40t^{\frac{1}{2}}$