Question	Scheme		Marks	AOs
1 (a)	$\log_{10} h = 2.25 - 0.235\log_{10} m$ $\Rightarrow h = 10^{2.25-0.235\log_{10} m}$ $\Rightarrow h = 10^{2.25} \times m^{-0.235}$	$h = pm^q$ $\Rightarrow \log_{10} h = \log_{10} p + \log_{10} m^q$ $\Rightarrow \log_{10} h = \log_{10} p + q\log_{10} m$	M1	1.1b
	Either one of $p = 10^{2.25}$ $q = -0.235$	Or either one of $\log_{10} p = 2.25$ $q = -0.235$	A1	1.1b
	$\Rightarrow p = 178$ and $q = -0.235$		A1	2.2a
			(3)	
(b)	$h = "178" \times 5^{"-0.235"}$	$\log_{10} h = "2.25" - "0.235" \log_{10} 5$	M1	3.1b
	$h = 122$	$h = 122$	A1	1.1b
	Reasonably accurate (to 2 sf) so suitable		A1ft	3.2b
			(3)	
(c)	"p" would be the (resting) heart rate (in bpm) of a mammal with a mass of 1 kg		B1	3.4
			(1)	
				(7 marks)

Notes

(a)

M1: Establishes a link between $h = pm^q$ and $\log_{10} h = 2.25 - 0.235\log_{10} m$.
May be implied by a correct equation in p or q

A1: For a correct equation in p or q

A1: $p = 178$ and $q = -0.235$

(b)

M1: Uses either model to set up an equation in h (or m)

A1: h = awrt 122. Condone h = awrt 122 bpm

A1ft: Comments on the suitability of the model. Follow through on their answer.

Requires a comment consistent with their answer from using the model.

E.g. It is a suitable model as it is only "3" bpm away from the real value ✓
Do not allow an argument stating that it should be the same.
It is an unsuitable model as "122" bpm is not equal to 119 bpm ×

(c)

B1: "p" would be the (resting) heart rate of a mammal with a mass of 1 kg

Question	Scheme	Marks	AOs
2 (a)	Uses or implies that $V = ad + b$	B1	3.3
	Uses both $40 = 80a + b$ and $25 = 200a + b$ to get either a or b	M1	3.1b
	Uses both $40 = 80a + b$ and $25 = 200a + b$ to get both a and b	dM1	1.1b
	$\Rightarrow V = -\frac{1}{8}d + 50$ o.e.	A1	1.1b
		(4)	
(b)(i)(ii)	States **either** that the initial volume was 50 {litres} **or** that the distance travelled was 400 {km}	B1 ft	3.4
	Attempts to find **both** answers by solving $0 = -\frac{1}{8}d + 50$ **and** $0 = 400 - 8V$	M1	3.4
	States **both** that the initial volume was 50 litres **and** that the distance travelled was 400 km	A1	3.2b
		(3)	
(c)	States, e.g., "Poor model" as 320km is significantly less than 400 km.	B1ft	3.5a
		(1)	
			(8 marks)

Notes:

(a)

B1: Attempts a linear model, i.e., uses or implies that $V = ad + b$ or $d = mV + c$ which may be in terms of, e.g., y and x

M1: Awarded for translating the problem in context and starting to solve.

It is scored when both $40 = 80a + b$ and $25 = 200a + b$ are written down and the candidate proceeds to find either a or b

Alternatively, scored when both $200 = 25m + c$ and $80 = 40m + c$ are written down and the candidate proceeds to find either m or c

You may just see $\pm\frac{25-40}{200-80}$ or $\pm\frac{200-80}{25-40}$ or 8km for every litre o.e. so check carefully for attempts at the gradient.

dM1: Uses $40 = 80a + b$ and $25 = 200a + b$ to find both a and b (or m and c)

Alternatively, if the gradient is found, proceeds to use one of the bullet points to find c, with the usual rules applying for straight line (coordinates must be used the correct way round, i.e., they would lead to the correct answer).

A1: $V = -\frac{1}{8}d + 50$ or exact equivalent, e.g., $d = 400 - 8V$ or $d + 8V = 400$ etc.

Withhold this mark if their answer is not stated in terms of V and d

Mark parts (b)(i) and (b)(ii) together. Note that they may restart and not use an equation.

B1ft: States **either** the initial volume was 50 {litres} **or** the distance travelled was 400 {km} but it must be clearly for the correct part, e.g., $V = 50$.

Follow through on their a and b (or m and c). This may be scored from $40 + \frac{80}{8}$ or $\frac{400}{8}$

M1: Complete attempt to find both answers. Must be from a **linear** model.

	Substitutes $V = 0$ and finds d by attempting to solve their $0 = -\frac{1}{8}d + 50$ **and** substitutes $d = 0$ and finds V by attempting to solve their $0 = 400 - 8V$ Note that one (or both) of these attempts may be implied by correct values ft their equations.
A1:	States both 50 litres and 400 km. Units are required to be correct for both values. It must be clear which answer applies to each part, which may be simply by correct units. Accept l or L for litres.
(c)	
B1ft:	**Main Scheme (comparing (b)(ii) with 320)** This mark is only available for answers from (b)(ii) if they are < 290 **or** > 350 Concludes **poor** model (o.e.) and states that 320 is **significantly** less than "400" (o.e.) Note that $320 << 400$ so it is a poor model is acceptable. It is not sufficient to say $320 \neq 400$ or $320 < 400$ so it is a poor model. Condone "the 400 is **too** far away from 320". **Alternative (finding remaining fuel after 320 km)** States **poor** model (o.e.) because after 320 km the model predicts there will be 10 litres left, which is **significantly** more than an empty tank / **much** too high compared to an empty tank (o.e.).

Question	Scheme	Marks	AOs
3(a)	$h = 2.3 - 1.7e^{0}$	M1	3.4
	Either 0.6 {m} or 60 cm	A1	1.1b
		(2)	
(b)	$\left\{\frac{dh}{dt} =\right\} 0.34e^{-0.2t}$	M1	3.1b
	At $t = 4 \Rightarrow$ Rate of growth is $0.34e^{-0.2\times4} = 0.15277...\{\text{m / year}\}$	dM1	3.4
	0.153 {m per year} = 15.3 cm {per year} *	A1*	1.1b
		(3)	
(c)	2.3 (m)	B1	2.2a
		(1)	
			(6 marks)

Notes:

(a)

M1: Substitutes $t = 0$ into $h = 2.3 - 1.7e^{-0.2t}$ Implied by e.g., $h = 2.3 - 1.7e^{-0}$ or $h = 0.6$

A1: Allow 0.6, 0.6 m, or 60 cm and isw after a correct height. Allow $\frac{3}{5}$

The M mark may be implied by A1.

(b)

M1: Links rate of change to gradient and differentiates $h = 2.3 - 1.7e^{-0.2t}$ to $ke^{-0.2t}$, $k \neq -1.7$

Accept, e.g., $-0.2\times-1.7e^{-0.2t}$ Must be seen in (b).

dM1: Substitutes $t = 4$ into $ke^{-0.2t}$, $k \neq -1.7$ and calculates its value.

A1*: Fully correct. Requires

- sight of $\left\{\frac{dh}{dt} =\right\} 0.34e^{-0.2t}$ o.e., e.g., $\left\{\frac{dh}{dt} =\right\} \frac{17}{50}e^{-0.2t}$ or $\left\{\frac{dh}{dt} =\right\} -0.2\times-1.7e^{-0.2t}$
- $\left\{\frac{dh}{dt} =\right\}$ awrt 0.153 {metres per year}
- changing to awrt 15.3 cm {per year}.

Note: Substituting $t = 4$ into $h = 2.3 - 1.7e^{-0.2t}$ gives $h = 1.536...$ scores M0dM0A0 unless differentiation and further correct work is seen separately.

(c)

B1: Allow 2.3, 2.3 m, or 230 cm

$2.2\dot{9}$ and 2.2999… which clearly continues are both acceptable, but 2.29999999 is not.

Question	Scheme	Marks	AOs
4 (a)	Attempts to use $h^2 = at + b$ with either $t = 2, h = 2.6$ or $t = 10, h = 5.1$	M1	3.1b
	Correct equations $2a + b = 6.76$ $10a + b = 26.01$	A1	1.1b
	Solves simultaneously to find values for a and b	dM1	1.1b
	$h^2 = 2.41t + 1.95$ cao	A1	3.3
		(4)	
(b)	Substitutes $t = 20$ into their $h^2 = 2.41t + 1.95$ and finds h or h^2 Or substitutes $h = 7$ into their $h^2 = 2.41t + 1.95$ and finds t	M1	3.4
	Compares the model with the true values and concludes "good model" with a minimal reason E.g. I Finds $h = 7.08\,(\text{m})$ and states that it is a good model as 7.08 (m) is close to 7 (m) E.g II Finds t =19.5 years and states that the model is accurate as 19.5 (years) $\approx$ 20 (years)	A1	3.5a
		(2)	
			(6 marks)
Notes:			

(a)

M1: For translating the problem into mathematics. Attempts to use the given equation o.e. with either of the pieces of information to form one correct equation.

Award for unsimplified equations as well, such as $2.6^2 = 2a + b$ or $2.6 = \sqrt{2a + b}$

A1: Two correct (and different) equations which may be unsimplified

dM1: Solves simultaneously to find values for *a* and *b*. It is dependent upon the previous M

Don't be too concerned with the process here as calculators may be used.

Score if values of *a* and *b* are reached from a pair of simultaneous equations

A1: Establishes **the full equation of the model** with values of *a* and *b* given to **exactly** 3sf. Award if seen in either (a) or (b). It is not scored for the values of *a* and *b*.

Allow either $h^2 = 2.41t + 1.95$ or $h = \sqrt{2.41t + 1.95}$

If they go on to square root each term from $h^2 = 2.41t + 1.95$ then it is A0. E.g. $h = 1.55t + 1.40$

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Special case for candidates who mistakenly use $h = at + b$

For $2.6 = 2a + b, \quad 5.1 = 10a + b \quad \Rightarrow h = 0.3125t + 1.975$ or $h = 0.313t + 1.98$

can score M1 correct equations with attempt to solve and A1 for either correct answer shown above.

These are the only marks available to them for a maximum mark of 1100 00

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(b)

M1: A full and valid attempt to

either substitute $t = 20$ into their $h^2 = 2.41t + 1.95$ o.e. and find a value for *h* or h^2

or substitute $h = 7$ into their $h^2 = 2.41t + 1.95$ o.e. and find a value for *t*

(to enable the candidate to compare real life data with that of the model.)

The equation of the model must be of the correct form, either $h^2 = at + b$ or $h = \sqrt{at + b}$

Do not be too concerned with the mechanics of the solution but the square or $\sqrt{}$ must have been used appropriately to enable the comparison to be made.

In cases with no working you will need to check the calculation

A1: Compares their *h*=7.08m to 7m o.e using h^2 or their *t* =19.5 years to 20 years and makes valid conclusion with reason.

For this mark you require

- a statement that it is a "good" or "accurate' ' model or similar wording
- a reason such as "the values are close", "the values are similar" or "the predicted values are within 5% of the true values."
- a model with equation $h^2 = a\,t + b$ o.e. where $a =$ awrt 2.4 and $b \in \left[1.9, 2.0\right]$
- correct calculations

Condone a statement like ‘ the model is pretty accurate as it predicted 7.08m and the actual value is 7m’

Do not allow incorrect statements such as the model is incorrect as it does not give 7 metres.

Do not allow just "the model gives an underestimate of the true value."

Do not allow ‘bad’ or ‘poor’ model