

| Question Number | Scheme                                                                                                                                                                                                                                                         | Marks                                 |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|
| <b>3(a)</b>     | $m = \frac{2.25 - 2}{5}$<br>$\log_{10} V = 0.05t + 2$                                                                                                                                                                                                          | M1<br>A1<br><b>(2)</b>                |
|                 |                                                                                                                                                                                                                                                                |                                       |
| <b>(b)</b>      | $\log_{10} V = 0.05t + 2 \Rightarrow V = 10^{0.05t+2}$<br>$a = 100$ or $b = 1.12$<br>$V = 100 \times (1.12)^t$                                                                                                                                                 | M1<br>A1<br>A1<br><b>(3)</b>          |
|                 |                                                                                                                                                                                                                                                                |                                       |
| <b>(c)</b>      | $\frac{dV}{dt} = 100 \times \ln 1.12 \times (1.12)^t \quad (= 11.33(1.12)^t)$<br>$100 \times \ln 1.12 \times (1.12)^T = 50 \Rightarrow (1.12)^T = \frac{50}{100 \ln 1.12}$<br>$(T =) \log_{1.12} \left( \frac{50}{100 \ln 1.12} \right) = \dots$<br>$(T =) 13$ | B1ft<br>M1<br>dM1<br>A1<br><b>(4)</b> |
|                 |                                                                                                                                                                                                                                                                |                                       |
|                 |                                                                                                                                                                                                                                                                | <b>(9 marks)</b>                      |

|              |                                                                                                                                                                                                                                                                                                                                   |                                                     |
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| <b>3 (i)</b> | $y = \frac{10^6}{x^3} \Rightarrow \log_{10} y = \log_{10} 10^6 - \log_{10} x^3 \Rightarrow \log_{10} y = 6 - 3 \log_{10} x$                                                                                                                                                                                                       |                                                     |
|              | <p>A graph showing a straight line on a coordinate system where the horizontal axis is labeled <math>\log_{10} x</math> and the vertical axis is labeled <math>\log_{10} y</math>. The line has a negative slope and passes through the points <math>(0, 6)</math> and <math>(2, 0)</math>.</p>                                   | B1<br>B1<br>B1<br><b>(3)</b>                        |
| <b>(ii)</b>  | <p>States <math>\log_3 N = 2t + 4</math></p> <p><math>N = 3^{2t+4} = 3^{2t} \times 3^4</math></p> <p><b>or</b> <math>\log_3 N = \log_3 a + t \log_3 b</math></p> <p><b>or</b> <math>\log_3 a = 4 \Rightarrow a = \dots</math> <b>or</b> <math>\log_3 b = 2 \Rightarrow b = \dots</math></p> <p><math>N = 81 \times 9^t</math></p> | B1<br>M1<br>Alcso<br><b>(3)</b><br><b>(6 marks)</b> |

|       |                                                                                                                                                                      |                                |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| 9.(a) | $x = 30e^{-0.2 \times 8} = 6.06 \text{ (mg)}$                                                                                                                        | M1, A1<br>(2)                  |
| (b)   | $x = 30e^{-0.2 \times 10} + 20e^{-0.2 \times 2} = 17.5 \text{ (mg)}^*$                                                                                               | B1*<br>(1)                     |
| (c)   | $30e^{-0.2 \times (T+8)} + 20e^{-0.2 \times T} = 10$<br>$(3e^{-1.6} + 2)e^{-0.2T} = 1$<br>$e^{-0.2T} = \frac{1}{3e^{-1.6} + 2}$<br>$T = 5 \ln(3e^{-1.6} + 2) = 4.79$ | M1<br>A1<br><br>dM1, A1<br>(4) |
|       |                                                                                                                                                                      | (7 marks)                      |

|       |                                                                                                                                                                      |                        |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| 7.(a) | States or implies that $A = 2500$<br>$10000 = 2500e^{k \times 8} \Rightarrow 8k = \ln 4 \Rightarrow k = \dots$<br>$\Rightarrow k = \frac{1}{8} \ln 4$ or awrt 0.1733 | B1<br>M1<br>A1<br>(3)  |
| (b)   | $\frac{dN}{dt} = 60000 \times -0.6e^{-0.6 \times 5} = -1792$ So decrease is 1790                                                                                     | M1, A1<br>(2)          |
| (c)   | $60000e^{-0.6t} = 2500e^{0.1733t}$<br>$24 = e^{0.1733t + 0.6t} \Rightarrow 0.1733t + 0.6t = \ln 24 \Rightarrow t = \dots$<br>$T = 4.11$                              | M1<br>dM1<br>A1<br>(3) |
|       |                                                                                                                                                                      | 8 marks                |

|      |                                                                                                                                                                                                                                                  |                        |
|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| 6(a) | $\log_{10} S = 4.5 - 0.006 \times 2 \Rightarrow S = 10^{4.5 - 0.006 \times 2} = 30800 \text{ km}^2$                                                                                                                                              | M1A1<br>(2)            |
| (b)  | $\log_{10} S = 4.5 - 0.006t \Rightarrow S = 10^{4.5 - 0.006t}$ (or $p = 10^{4.5}$ or $q = 10^{-0.006}$ )<br>$S = 10^{4.5 - 0.006t} = 10^{4.5} \times (10^{-0.006})^t$ (or $p = 10^{4.5}$ and $q = 10^{-0.006}$ )<br>$S = 31600 \times (0.986)^t$ | M1<br>dM1<br>A1<br>(3) |
| (c)  | E.g. The proportion of area covered by coral reefs retained from year to year.                                                                                                                                                                   | B1<br>(1)              |
|      |                                                                                                                                                                                                                                                  | (6 marks)              |

|      |                                                   |     |
|------|---------------------------------------------------|-----|
| 3(a) | $\log_{10} y = \pm \frac{2}{3.5} \log_{10} x - 2$ | M1  |
|      | $\log_{10} y = -\frac{4}{7} \log_{10} x - 2$      | A1  |
|      |                                                   | (2) |

|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| (b) | $\log_{10} y = -\frac{4}{7} \log_{10} x - 2 \Rightarrow$ $y = 10^{\left(-\frac{4}{7} \log_{10} x - 2\right)} \text{ or } y = 10^{\left(\log_{10} x^{-\frac{4}{7} - 2}\right)} \text{ or } y = 10^{-\frac{4}{7} \log_{10} x} \times 10^{-2}$ <p>or e.g.</p> $\log_{10} y = \log_{10} x^{-\frac{4}{7} - 2} \Rightarrow \log_{10} \frac{y}{x^{\frac{4}{7}}} = -2$ <p>or e.g.</p> $\log_{10} y = -\log_{10} x^{\frac{4}{7}} - 2 \Rightarrow \log_{10} yx^{\frac{4}{7}} = -2$ | M1             |
|     | $y = 10^{\left(\log_{10} x^{-\frac{4}{7} - 2}\right)} \text{ or } y = 10^{-\frac{4}{7} \log_{10} x} \times 10^{-2} \Rightarrow y = x^{-\frac{4}{7}} \times 10^{-2}$ <p>or e.g.</p> $10^{\log_{10} \frac{y}{x^{\frac{4}{7}}}} = 10^{-2} \Rightarrow \frac{y}{x^{\frac{4}{7}}} = 10^{-2} \text{ or } 10^{\log_{10} yx^{\frac{4}{7}}} = 10^{-2} \Rightarrow yx^{\frac{4}{7}} = 10^{-2}$                                                                                     | dM1            |
|     | $y = \frac{1}{100} x^{-\frac{4}{7}} \text{ oe}$                                                                                                                                                                                                                                                                                                                                                                                                                          | A1             |
|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | (3)            |
|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Total 5</b> |

| Question Number | Scheme                                                                                                                                                                  | Marks            |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| <b>5(a)</b>     | $\left(\frac{4000e^0}{19+e^0}\right) = 200$                                                                                                                             | B1               |
|                 |                                                                                                                                                                         | (1)              |
| <b>(b)</b>      | $\frac{dN}{dt} = \frac{(19+e^{0.2t}) \times 400e^{0.1t} - 4000e^{0.1t} \times 0.2e^{0.2t}}{(19+e^{0.2t})^2}$                                                            | M1A1             |
|                 |                                                                                                                                                                         | (2)              |
| <b>(c)</b>      | $(19+e^{0.2t}) \times 400e^{0.1t} - 4000e^{0.1t} \times 0.2e^{0.2t} = 0 \Rightarrow e^{0.2T} = 19$                                                                      | M1A1             |
|                 |                                                                                                                                                                         | (2)              |
| <b>(d)</b>      | $e^{0.2T} = 19 \Rightarrow T = \frac{\ln 19}{0.2} (=14.7...)$ $N = \frac{4000e^{0.1 \times 14.7}}{19+e^{0.2 \times 14.7}} = 458.8... \Rightarrow 459 \text{ squirrels}$ | M1<br>dM1A1      |
|                 |                                                                                                                                                                         | (3)              |
|                 |                                                                                                                                                                         | <b>(8 marks)</b> |

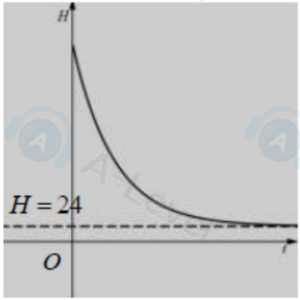
|      |                                                                     |           |
|------|---------------------------------------------------------------------|-----------|
| 4(a) | $A = 93$                                                            | B1        |
|      |                                                                     | (1)       |
| (b)  | $100 = 125 - "93"e^{-0.109T} \Rightarrow Ae^{-0.109T} = \dots$      | M1        |
|      | $Ae^{kT} = B \Rightarrow T = \frac{\ln\left(\frac{B}{A}\right)}{k}$ | dM1       |
|      | $T = 12.05$                                                         | A1        |
|      |                                                                     | (3)       |
| (c)  | $\frac{dN}{dt} = 0.109 \times "93"e^{-0.109 \times 7}$              | M1        |
|      | 4 730 (total sales per month)                                       | A1        |
|      |                                                                     | (2)       |
| (d)  | The limit is 125 000 / the model has a limit below 150 000          | B1        |
|      |                                                                     | (1)       |
|      |                                                                     | (7 marks) |

| Question Number | Scheme                                                                | Marks     |
|-----------------|-----------------------------------------------------------------------|-----------|
| 3(a)            | $\log_{10} D = 1.04 + 0.38t \Rightarrow D = 10^{1.04+0.38t}$          | M1        |
|                 | or<br>$a = 10^{1.04}$ or $b = 10^{0.38}$                              |           |
|                 | $a = \text{awrt } 10.96$ or $b = \text{awrt } 2.399$                  | A1        |
|                 | $D = 10.96 \times 2.399^t$                                            | A1        |
| (b)             |                                                                       | (3)       |
|                 | $45000 = "10.96" \times "2.399"^T \Rightarrow T = \dots$              | M1        |
|                 | or<br>$\log_{10} 45000 = 1.04 + 0.38T \Rightarrow T = \dots$          |           |
| (c)             | $\text{awrt } 9.51$                                                   | A1        |
|                 |                                                                       | (2)       |
|                 | $D = "10.96" \times "2.399"^{12} \Rightarrow D = \dots$               | M1        |
| (c)             | or<br>$\log_{10} D = 1.04 + 0.38 \times 12 \Rightarrow D = \dots$     |           |
|                 | or<br>$350000 = "10.96" \times "2.399"^t \Rightarrow t = \dots$       |           |
|                 | or<br>$\log_{10} 350000 = 1.04 + 0.38 \times t \Rightarrow t = \dots$ |           |
| (c)             | $D = \text{awrt } (\text{£})400\ 000 \Rightarrow \text{yes}$          | A1        |
|                 | or<br>$t = \text{awrt } 11.9 \Rightarrow \text{yes}$                  |           |
|                 |                                                                       | (2)       |
|                 |                                                                       | (7 marks) |

| Question Number | Scheme                                                                       | Marks          |
|-----------------|------------------------------------------------------------------------------|----------------|
| <b>3(a)</b>     | $\log_{10} y = \frac{5}{16}x + 1.5$                                          | M1A1           |
|                 |                                                                              | <b>(2)</b>     |
| <b>(b)</b>      | $\log_{10} y = \frac{5}{16}x + 1.5 \Rightarrow y = 10^{\frac{5}{16}x + 1.5}$ | M1             |
|                 | $\Rightarrow y = 10^{\frac{5}{16}x} \times 10^{1.5}$                         | M1             |
|                 | $y = 31.6 \times 2.05^x$                                                     | A1             |
|                 |                                                                              | <b>(3)</b>     |
|                 |                                                                              | <b>Total 5</b> |

|              |                                                                 |                  |
|--------------|-----------------------------------------------------------------|------------------|
| <b>2 (a)</b> | 10 m <sup>2</sup>                                               | B1               |
|              |                                                                 | <b>(1)</b>       |
| <b>(b)</b>   | $\log_{10} 25 = 1 + 0.03T \Rightarrow T = \dots$<br>$T = 13.26$ | M1<br>A1cso      |
|              |                                                                 | <b>(2)</b>       |
|              |                                                                 | <b>(3 marks)</b> |

| Question Number | Scheme                                                                                                                                                                                                                | Marks            |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| <b>5(a)</b>     | $(A=)8$                                                                                                                                                                                                               | B1               |
|                 |                                                                                                                                                                                                                       | <b>(1)</b>       |
| <b>(b)</b>      | $16 = 10 + 8e^{-Bt} \Rightarrow e^{-Bt} = \dots$                                                                                                                                                                      | M1               |
|                 | $e^{-45B} = \frac{3}{4} \Rightarrow -45B = \ln \frac{3}{4} \Rightarrow B = \dots$                                                                                                                                     | dM1              |
|                 | $B = \text{awrt } 0.00639$                                                                                                                                                                                            | A1               |
|                 |                                                                                                                                                                                                                       | <b>(3)</b>       |
| <b>(c)</b>      | $\frac{dT}{dt} = -8 \times \frac{1}{45} \ln \left( \frac{4}{3} \right) \times e^{-\frac{1}{45} \ln \left( \frac{4}{3} \right) \times 2} = \dots$                                                                      | M1               |
|                 | $= -0.0505$                                                                                                                                                                                                           | A1               |
|                 |                                                                                                                                                                                                                       | <b>(2)</b>       |
| <b>(d)</b>      | The temperature has a (lower) limit of 10 °C<br><b>or</b><br>$5 = 10 + 8e^{-Bt} \Rightarrow e^{-Bt} = -\frac{5}{8}$<br>e.g. which is not possible or cannot be solved or you cannot find the log of a negative number | B1               |
|                 |                                                                                                                                                                                                                       | <b>(1)</b>       |
|                 |                                                                                                                                                                                                                       | <b>(7 marks)</b> |

|       |                                                                                                                                                   |                  |     |
|-------|---------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-----|
| 5 (a) | 304(°C)                                                                                                                                           | B1               | (1) |
| (b)   |  <p>Shape or Asymptote<br/>Fully correct Shape and Asymptote</p> | M1<br>A1         | (2) |
| (c)   | $144 = 280e^{-0.05t} + 24 \Rightarrow 280e^{-0.05t} = 120$<br>Correct use of lns $\Rightarrow -0.05t = \ln \frac{120}{280} \Rightarrow t = 16.95$ | M1<br>dM1 A1     | (3) |
| (d)   | $\left(\frac{dH}{dt}\right) - 0.05 \times 280e^{-0.05t}$<br>$\frac{dH}{dt} = -0.05 \times (H - 24) \Rightarrow \frac{dH}{dt} = 1.2 - 0.05H$       | M1<br>M1, A1cso  | (3) |
|       |                                                                                                                                                   | <b>(9 marks)</b> |     |

| Question Number | Scheme                                                                                                                                                 | Marks            |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| 2 (a) (i)       | $\log_6 T = 4 - 2 \log_6 x$                                                                                                                            | B1               |
| (ii)            | E.g. $\log_6 T = 4 - 2 \log_6 216 \Rightarrow \log_6 T = 4 - 2 \times 3 = -2 \Rightarrow T = \dots$<br>$\Rightarrow T = 6^{-2} = \frac{1}{36}$         | M1<br>A1         |
| (b)             | $\log_6 T = 4 - 2 \log_6 x \Rightarrow T = 6^{4 - 2 \log_6 x}$<br>$\Rightarrow T = 6^4 \times 6^{\log_6 x^{-2}}$<br>$\Rightarrow T = \frac{1296}{x^2}$ | M1<br>dM1<br>A1  |
|                 |                                                                                                                                                        | <b>(6 marks)</b> |



|       |                                                                                                                 |                 |
|-------|-----------------------------------------------------------------------------------------------------------------|-----------------|
| 8 (a) | 52 b.p.m.                                                                                                       | B1              |
|       |                                                                                                                 | (1)             |
| (b)   | 32 b.p.m.                                                                                                       | B1              |
|       |                                                                                                                 | (1)             |
| (c)   | $\frac{dH}{dt} = -8e^{-0.2t} + 18e^{-0.9t}$                                                                     | M1, A1          |
|       | Sets $-8e^{-0.2t} + 18e^{-0.9t} = 0 \Rightarrow 4e^{0.7t} = 9$                                                  | dM1             |
|       | $\Rightarrow 0.7t = \ln \frac{9}{4} \Rightarrow t = \dots$                                                      | M1              |
|       | $T = 1.158$ (minutes)                                                                                           | A1              |
|       |                                                                                                                 | (5)             |
| (d)   | $37 = 32 + 40e^{-0.2t} - 20e^{-0.9t} \Rightarrow e^{-0.2t} = \frac{1 + 4e^{-0.9t}}{8}$                          | M1              |
|       | $\Rightarrow e^{0.2t} = \frac{8}{1 + 4e^{-0.9t}} \Rightarrow t = 5 \ln \left( \frac{8}{1 + 4e^{-0.9t}} \right)$ | A1*             |
|       |                                                                                                                 | (2)             |
| (e)   | $t_2 = 5 \ln \left( \frac{8}{1 + 4e^{-0.9 \times 10}} \right) = \dots$                                          | M1              |
|       | $(t_2) = \text{awrt } 10.3947$                                                                                  | A1              |
|       | $(M) = 10.3955$                                                                                                 | A 1             |
|       |                                                                                                                 | (3)             |
|       |                                                                                                                 | <b>Total 12</b> |

| Question Number | Scheme                                                                                                      | Marks |
|-----------------|-------------------------------------------------------------------------------------------------------------|-------|
| 6(a)            | $\theta = 75, t = 0 \Rightarrow 75 = 21 + A \Rightarrow A = \dots$                                          | M1    |
|                 | $A = 54$                                                                                                    | A1    |
|                 |                                                                                                             | (2)   |
| (b)             | $\theta = 21 + 54e^{-kt} \Rightarrow 25 = 21 + 54e^{-5k}$                                                   | M1    |
|                 | $54e^{-5k} = 4 \Rightarrow e^{-5k} = \frac{2}{27} \Rightarrow -5k = \ln \frac{2}{27} \Rightarrow k = \dots$ | M1    |
|                 | $k = -\frac{1}{5} \ln \frac{2}{27} = 0.521$                                                                 | A1    |
|                 |                                                                                                             | (3)   |

|     |                                                                                                                                          |     |
|-----|------------------------------------------------------------------------------------------------------------------------------------------|-----|
| (c) | $\theta = 21 + 54e^{-0.521t} \Rightarrow \frac{d\theta}{dt} = -28.1\dots e^{-0.521t}$                                                    | M1  |
|     | $-28.1\dots e^{-0.521T} = -9 \Rightarrow e^{-0.521T} = \frac{9}{28.1\dots} \Rightarrow -0.521T = \ln \left( \frac{9}{28.1\dots} \right)$ | dM1 |
|     | $\Rightarrow T = \ln \left( \frac{9}{28.1\dots} \right) \div -0.521$                                                                     |     |
|     | $= 2.19$                                                                                                                                 | A1  |
|     |                                                                                                                                          | (3) |

|              |                                                                                  |                |
|--------------|----------------------------------------------------------------------------------|----------------|
| <b>4 (a)</b> | $\log_{10} N = 2 \Rightarrow N = 100$                                            | B1             |
|              |                                                                                  | <b>(1)</b>     |
| <b>(b)</b>   | $\log_{10} N = 0.35t + 2 \Rightarrow N = 10^{0.35t+2}$                           | M1             |
|              | $\Rightarrow N = 10^{0.35t} \times 10^2$                                         | dM1            |
|              | $\Rightarrow N = 100 \times 2.24^t$                                              | A1             |
|              |                                                                                  | <b>(3)</b>     |
| <b>(c)</b>   | Rate of growth at 5 hours is $\frac{dN}{dt} = 100 \times \ln 2.24 \times 2.24^5$ | M1             |
|              | Allow an answer in the range 4530 to 4550 (bacteria per hour)                    | A1             |
|              |                                                                                  | <b>(2)</b>     |
|              |                                                                                  | <b>Total 6</b> |