

| Question Number | Scheme                                                                                                                               | Marks | AOs  |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------|-------|------|
| 13 (a)          | $23 = A + 12e^0 + 9e^0 \Rightarrow A = \dots$                                                                                        | M1    | 3.1b |
|                 | $V = 2 + 12e^{-0.2t} + 9e^{-0.1t}$                                                                                                   | A1    | 3.3  |
|                 |                                                                                                                                      | (2)   |      |
| (b)             | $5 = 2 + 12e^{-0.2T} + 9e^{-0.1T} \Rightarrow 12e^{-0.2T} + 9e^{-0.1T} - 3 = 0$                                                      | M1    | 3.4  |
|                 | e.g. $\Rightarrow 3(4e^{-0.1T} - 1)(e^{-0.1T} + 1) = 0 \Rightarrow e^{-0.1T} = \dots$<br><br>or implied by $e^{-0.1T} = \frac{1}{4}$ | dM1   | 3.1a |
|                 | $\Rightarrow e^{-0.1T} = \frac{1}{4} \Rightarrow -0.1T = \ln \frac{1}{4}$                                                            | ddM1  | 2.1  |
|                 | $\{T = \}$ awrt 13.86                                                                                                                | A1    | 1.1b |
|                 |                                                                                                                                      | (4)   |      |
| (6 marks)       |                                                                                                                                      |       |      |
| Notes:          |                                                                                                                                      |       |      |

- (a)

**M1:** Attempts to find the value of  $A$  using  $t = 0$  and  $V = 23$  (**not**  $V = 23000$ ).

**A1:** Correct complete equation for the model  $V = 2 + 12e^{-0.2t} + 9e^{-0.1t}$  including  $V =$   
If just  $A = 2$  seen in part (a) this mark may be awarded for a complete model seen in part (b).
- (b)

**Note:** Use of  $t$  or e.g.  $x$  in place of  $T$  is acceptable throughout this part of the question.

**M1:** Uses their model with  $V = 5$  and their numerical  $A$  and proceeds to a 3TQ which may not all be on one side. The constant terms must be combined.  
Note that they may not realise that they have a 3TQ but will score the mark for reaching an appropriate form.  
Allow this mark to be scored for  $V = 5000$  if they have used  $V = 23000$  in (a) but they are not eligible to score any more marks in this question and condone slips e.g. 50000 or 2300.

**dM1:** For the key step in recognising the equation as a quadratic equation in  $e^{\pm 0.1T}$  and attempting to solve. The usual methods apply for solving their 3TQ and roots for  $e^{\pm 0.1T}$  may come from a calculator provided they are correct to 2sf. This is **not** implied by a correct value for  $T$  **only**.  
Must be clearly solving for  $e^{\pm 0.1T}$ , so if they replace with  $X$  then they must revert back to  $e^{\pm 0.1T}$   
Note that the equation in  $e^{0.1T}$  is  $3e^{0.2T} - 9e^{0.1T} - 12 = 0$  which leads to  $e^{0.1T} = 4$   
Dependent on the previous method mark.

**ddM1:** Full and complete method to find  $T$  with correct use of lns but condone slips on dividing by  $\pm 0.1$   
Dependent upon both previous method marks.

**A1:**  $\{t / T = \}$  awrt 13.86 following award of all previous marks. Ignore any reference to units.  
Must be a decimal and not just  $\frac{1}{-0.1} \ln \frac{1}{4}$  or  $10 \ln 4$