12	**(a)**	**(i)**	$\frac{d\theta}{dt} = -k$	**B1** **[1]**	**3.3**	Allow $\frac{d\theta}{dt} = k$ **or** $\frac{d\theta}{dt} = -3.5$	Both sides of differential equation required
		(ii)	$\theta = -3.5t + c$ $\theta = 160 - 3.5t$	**M1** **A1** **[2]**	**3.4** **1.1**	Obtain equation of the form $\theta = \pm 3.5t + c$, where c could already be numerical and possibly incorrect Obtain correct equation	Not dependent on correct differential equation in **(i)** **Alt method** For M1, integrate to get $\theta = kt + c$, then use (0, 160) and (10, 125) to attempt c and hence k

Question			Answer	Marks	AO	Guidance	
		(iii)	The model would predict that the temperature would fall below room temperature, and eventually below freezing point	**B1** **[1]**	**3.5b**	Any sensible comment	Cooling rate unlikely to be linear Identify that limit (ie room temperature) will be reached
	(b)	**(i)**	$\frac{\mathrm{d}\theta}{\mathrm{d}t} = -k(\theta - 20)$	**B1** **[1]**	**3.3**	Allow $\frac{\mathrm{d}\theta}{\mathrm{d}t} = k(\theta - 20)$	Both sides of differential equation required ISW if $k = -3.5$ used once correct equation seen (but B0 if only ever seen with -3.5)
		(ii)	$\int \frac{1}{\theta - 20}\mathrm{d}\theta = \int -k\,\mathrm{d}t$	**M1**	**3.1a**	Separate variables (or invert each side) and attempt integration	Allow M1 for integration of a differential equation not of this form eg $\frac{\mathrm{d}\theta}{\mathrm{d}t} = \frac{-k}{(\theta - 20)}$, as long as t and/or θ are involved – must be attempt at correct rearrangement of their diff eqn

Question			Answer	Marks	AO	Guidance	
			$\ln\lvert\theta - 20\rvert = -kt + c$	**A1**	**1.1**	Obtain correct integral	Or $\ln\lvert\theta - 20\rvert = kt + c$ Condone brackets not modulus
			ln140 = c	**M1**	**3.4**	Use t = 0, θ = 160 in an equation involving both k and c	Equation must be from integration attempt, but could follow M0 As far as numerical c or k Using both pairs of values as limits in a definite integral is M2
			ln105 = –10k + ln 140 k = – 0.1ln0.75	**M1**	**1.1a**	Use t = 10, θ = 125 in an equation involving both k and c (c possibly now numerical)	As far as numerical c and k
			$\ln\lvert\theta - 20\rvert = (0.1\ln 0.75)t + \ln 140$ $\theta - 20 = \mathrm{e}^{(0\ 1\ln 0\ 75)t + \ln 140} = 140\mathrm{e}^{(0\ 1\ln 0\ 75)t}$	**M1**	**1.1**	Attempt to make θ the subject	As far as correctly removing logs Equation must now be of the correct form ie $\ln\lvert a\theta + b\rvert = ct + d$ Could still be in terms of c and k to give eg $\theta = A\mathrm{e}^{kt} + 20$
			$\theta = 20 + 140\mathrm{e}^{(0\ 1\ln 0\ 75)t}$	**A1**	**1.1**	Obtain correct equation Allow – 0.0288 (or better) for 0.1ln0.75 and/or 4.94 (or better) for ln140	Allow $\theta = 20 + \mathrm{e}^{(0.1\ln 0.75)t + \ln 140}$ Could see $\theta = 140(0.75)^{0\ 1t} + 20$
				[6]			
	(c)		25 = 160 – 3.5t $\Rightarrow$ t = 38.6 mins ln5 = (0.1ln0.75)t + ln140 $\Rightarrow$ t = 115.8 mins	**M1**	**3.4**	Use θ = 25 in both of their equations to find values for t	As far as two numerical values for t
			77 minutes	**A1**	**3.4**	Obtain 77 minutes	Accept any answer rounding to 77, with no errors seen
				[2]			