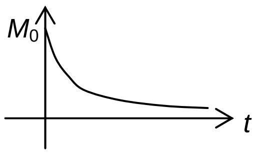
1(i) $T = 25 + ae^{-kt}$. When $t = 0$, $T = 100$ $\Rightarrow$ $100 = 25 + ae^0$ $\Rightarrow$ $a = 75$ When $t = 3$, $T = 80$ $\Rightarrow$ $80 = 25 + 75e^{-3k}$ $\Rightarrow$ $e^{-3k} = 55/75$ $\Rightarrow$ $-3k = \ln(55/75)$, $k = -\ln(55/75) / 3$ $= 0.1034$	M1 A1 M1 M1 A1cao [5]	substituting $t = 0$ and $T = 100$ into their equation (even if this is an incorrect version of the given equation) substituting $t = 3$ and $T = 80$ into (their) equation taking lns correctly at any stage 0.1 or better or $-\frac{1}{3}\ln(\frac{55}{75})$ o.e. if final answer
(ii) (A) $T = 25 + 75e^{-0\ 1034\times 5}$ $= 69.72$ (B) 25°C	M1 A1 B1cao [3]	substituting $t = 5$ into their equation 69.5 to 70.5, condone inaccurate rounding due to value of k.

2 (i) When $t = 0$, $P = 5 + a = 8$ $\Rightarrow a = 3$ When $t = 1$, $5 + 3e^{-b} = 6$ $\Rightarrow e^{-b} = 1/3$ $\Rightarrow -b = \ln 1/3$ $\Rightarrow b = \ln 3 = 1.10$ (3 s.f.)	M1 A1 M1 M1 A1ft	substituting $t = 0$ into equation Forming equation using their a Taking lns on correct re-arrangement (ft their a)
(ii) 5 million	B1 [6]	or $P = 5$

3 (i) ln $(3x^2)$	B1 B1	2ln x = ln x^2 ln x^2 + ln 3 = ln $3x^2$
(ii) ln $3x^2$ = ln$(5x + 2)$ $\Rightarrow 3x^2 = 5x + 2$ $\Rightarrow 3x^2 - 5x - 2 = 0$*	M1 E1	Anti-logging
(iii) $(3x + 1)(x - 2) = 0$ $\Rightarrow x = -1/3$ or 2	M1 A1cao	Factorising or quadratic formula
$x = -1/3$ is not valid as ln $(-1/3)$ is not defined	B1ft	ft on one positive and one negative root
	[7]	

4 (i) 	B1 B1	Correct shape Passes through (0, M_0)
(ii) $\frac{M}{M_0} = e^{-0\ 000121 \times 5730} = e^{-0\ 6933} \approx \frac{1}{2}$	M1 E1	substituting $k = -0.00121$ and $t = 5730$ into equation (or ln eqn) showing that $M \approx ½\ M_0$
(iii) $\frac{M}{M_0} = e^{-kT} = \frac{1}{2}$ $\Rightarrow \ln\frac{1}{2} = -kT$ $\Rightarrow \ln 2 = kT$ $\Rightarrow T = \frac{\ln 2}{k}$*	M1 M1 E1	substituting $M/M_0 = ½$ into equation (oe) taking lns correctly
(iv) $T = \frac{\ln 2}{2.88 \times 10^{-5}} \approx 24\,000$ years	B1 [8]	24 000 or better

5	$T = 30 + 20e^0 = 50$ $dT/dt = -0.05 \times 20e^{-0\ 05t} = -e^{-0\ 05t}$ When $t = 0$, $dT/dt = -1$ When $T = 40$, $40 = 30 + 20e^{-0\ 05t}$ $\Rightarrow$ $e^{-0\ 05t} = ½$ $\Rightarrow$ $-0.05t = \ln ½$ $\Rightarrow$ $t = -20 \ln ½ = 13.86..$ (mins)	B1 M1 A1cao M1 M1 A1cao [6]	50 correct derivative –1 (or 1) substituting $T = 40$ taking lns correctly or trial and improvement – one value above and one below or 13.9 or 13 mins 52 secs or better www condone secs

Question			Answer	Marks	Guidance	
6	(i)		$\frac{dy}{dx} = \sin 2x + 2x\cos 2x$	M1	d/dx(sin 2x) = 2cos 2x soi	can be inferred from dy/dx = 2x cos 2x
				A1	cao, mark final answer	e.g. dy/dx = tan 2x + 2x is A0
			dy/dx = 0 when sin 2x + 2x cos 2x = 0	M1	equating their derivative to zero, **provided it has two terms**	
			$\Rightarrow \frac{\sin 2x + 2x\cos 2x}{\cos 2x} = 0$			
			$\Rightarrow$ tan 2x + 2x = 0 *	A1 **[4]**	must show evidence of division by cos 2x	
	(ii)		At P, x sin 2x = 0	M1		Finding $x = \pi/2$ using the given line equation is M0
			$\Rightarrow \sin 2x = 0,\ 2x = (0),\ \pi \Rightarrow x = \pi/2$	A1	$x = \pi/2$	
			At P, dy/dx = $\sin\pi + 2(\pi/2)\cos\pi = -\pi$	B1 ft	ft their $\pi/2$ and their derivative	
			Eqn of tangent: $y - 0 = -\pi(x - \pi/2)$	M1	substituting 0, their $\pi/2$ and their $-\pi$ into $y - y_1 = m(x - x_1)$	or their $-\pi$ into $y = mx+c$, and then evaluating c: $y = (-\pi)x + c$,
			$\Rightarrow y = -\pi x + \pi^2/2$			$0 = (-\pi)(\pi/2) + c$ M1
			$\Rightarrow 2\pi x + 2y = \pi^2$ *	A1	**NB AG**	$\Rightarrow c = \pi^2/2$ $\Rightarrow y = -\pi x + \pi^2/2 \Rightarrow 2\pi x + 2y = \pi^2$ *A1
			When x = 0, $y = \pi^2/2$, so Q is $(0, \pi^2/2)$	M1A1 **[7]**	can isw inexact answers from $\pi^2/2$	
	(iii)		Area = triangle OPQ – area under curve	M1	soi (or area under PQ – area under curve	area under line may be expressed in integral form
			Triangle OPQ = ½ × $\pi/2 \times \pi^2/2$ [= $\pi^3/8$]	B1cao	allow art 3.9	or using integral: $\int_0^{\pi/2}(\frac{1}{2}\pi^2 - \pi x)\,dx = \left[\frac{1}{2}\pi^2 x - \frac{1}{2}\pi x^2\right]_0^{\pi/2} = \frac{\pi^3}{4} - \frac{\pi^3}{8} [= \frac{\pi^3}{8}]$
			Parts: u = x , dv/dx = sin 2x du/dx = 1, v = –½ cos2x	M1	condone v = k cos2x soi	v can be inferred from their 'uv'
			$\int_0^{\pi/2} x\sin 2x\,dx = \left[-\frac{1}{2}x\cos 2x\right]_0^{\pi/2} - \int_0^{\pi/2} -\frac{1}{2}\cos 2x\,dx$	A1ft	ft their v = –½ cos2x, ignore limits	
			$= \left[-\frac{1}{2}x\cos 2x + \frac{1}{4}\sin 2x\right]_0^{\pi/2}$	A1	[– ½ x cos 2x + ¼ sin 2x] o.e., must be correct at this stage, ignore limits	
			$= -\frac{1}{4}\pi\cos\pi + \frac{1}{4}\sin\pi - (-0\cos 0 + \frac{1}{4}\sin 0) = \frac{1}{4}\pi[-0]$	A1cao	(so dep previous A1)	
			So shaded area = $\pi^3/8 - \pi/4 = \pi(\pi^2 - 2)/8$*	A1 **[7]**	**NB AG** must be from fully correct work	