

Question		Answer	Marks	AO	Guidance
16	(a)	DR			
		$\int dP = \int (72t - 108)e^{-0.8t} dt$ oe	B1	3.1a	separation of variables; condone omission of integral signs or of dt ; allow P instead of $\int dP$ on left hand side
		$\frac{-108}{-0.8}e^{-0.8t}$ oe seen	B1	2.1	
		$72 \left[t \frac{e^{-0.8t}}{-0.8} - \int \frac{e^{-0.8t}}{-0.8} dt \right]$ oe	M1*	1.1	integration by parts; allow sign errors only
			A1	1.1	all correct;
		$[P =] -90te^{-0.8t} - 112.5e^{-0.8t} + 135e^{-0.8t}[+c]$ oe	A1	1.1	allow omission of $+c$; allow unsimplified
		$58.5 = -90 \times 0 \times e^0 + 22.5e^0 + c$ oe	M1dep*	3.3	may be awarded after rearrangement; must see constant of integration; NB if expression incorrect, need to see full substitution for M1
		$P = 36 + 22.5e^{-0.8t} - 90te^{-0.8t}$	A1	1.1	allow just $c = 36$ as long as “ $P =$ ” seen following completion of integration; allow eg $P = 36 + 45(\frac{1}{2}e^{-0.8t} - 2te^{-0.8t})$; like terms must be collected and fractions must be in lowest terms
		Alternative method			
		$\int dP = \int (72t - 108)e^{-0.8t} dt$ oe	B1		separation of variables; condone omission of integral signs or of dt ; allow P instead of $\int dP$ on left hand side
		$\frac{e^{-0.8t}}{-0.8}$ oe seen	B1		may be embedded in integration by parts

Question		Answer	Marks	AO	Guidance
		$(72t - 108) \frac{e^{-0.8t}}{-0.8} - \int 72 \frac{e^{-0.8t}}{-0.8} dt$ $[P =] - 90te^{-0.8t} - 112.5e^{-0.8t} + 135e^{-0.8t} + c$ $58.5 = -90 \times 0 \times e^0 + 22.5e^0 + c \text{ oe}$ $P = 36 + 22.5e^{-0.8t} - 90te^{-0.8t}$	M1* A1 A1 M1dep* A1		integration by parts; allow sign errors only all correct all correct; allow omission of + c; allow unsimplified may be awarded after rearrangement; must see constant of integration allow just $c = 36$ as long as “ $P =$ ” seen following completion of integration; allow eg $P = 36 + 45(\frac{1}{2}e^{-0.8t} - 2te^{-0.8t})$; like terms must be collected and fractions must be in lowest terms
			[7]		
16	(b)	DR as $t \rightarrow \infty, (k)e^{-0.8t} \rightarrow 0$ so $P \rightarrow 36$. [Hence the model predicts that the population of puffins] does not recover to 58.5 thousand	M1 A1 [2]	3.4 1.1	or $\lim_{t \rightarrow \infty} (k) e^{-0.8t} = 0$; k is a constant; allow eg as t tends to infinity / as t becomes very large / in the long term, $(k)e^{-0.8t}$ tends to / converges to / approaches zero oe do not allow eg substitution of $t = \infty$ condone $P = 36$