Question	Scheme	Marks	AOs
9(a)	$\mathrm{f}(x)=4\left(x^2-2\right)\mathrm{e}^{-2x}$		
	Differentiates to $\mathrm{e}^{-2x}\times 8x+4\left(x^2-2\right)\times -2\mathrm{e}^{-2x}$	M1 A1	1.1b 1.1b
	$\mathrm{f}'(x)=8\mathrm{e}^{-2x}\left\{x-\left(x^2-2\right)\right\}=8\left(2+x-x^2\right)\mathrm{e}^{-2x}$ *	A1*	2.1
		(3)	
(b)	States roots of $\mathrm{f}'(x)=0$ $\quad x=-1,2$	B1	1.1b
	Substitutes one *x* value to find a *y* value	M1	1.1b
	Stationary points are $\left(-1,-4\mathrm{e}^2\right)$ and $\left(2,8\mathrm{e}^{-4}\right)$	A1	1.1b
		(3)	
(c)	(i) Range $\left[-8\mathrm{e}^2,\infty\right)$ o.e. such as $\mathrm{g}(x)\geqslant -8\mathrm{e}^2$	B1ft	2.5
	(ii) For • Either attempting to find $2\mathrm{f}(0)-3=2\times -8-3=(-19)$ and identifying this as the **lower bound** • Or attempting to find $2\times$"$8\mathrm{e}^{-4}$"-3 and identifying this as the **upper bound**	M1	3.1a
	Range $\left[-19,16\mathrm{e}^{-4}-3\right]$	A1	1.1b
		(3)	
			(9 marks)
Notes:			

(a)

M1: Attempts the product rule and uses $\mathrm{e}^{-2x}\to k\mathrm{e}^{-2x},\quad k\neq 0$

If candidate states $u=4(x^2-2), v=\mathrm{e}^{-2x}$ with $u'=....,v'=...\mathrm{e}^{-2x}$ it can be implied by their $vu'+uv'$

If they just write down an answer without working award for $\mathrm{f}'(x)=px\mathrm{e}^{-2x}\pm q\left(x^2-2\right)\mathrm{e}^{-2x}$

They may multiply out first $\mathrm{f}(x)=4x^2\mathrm{e}^{-2x}-8\mathrm{e}^{-2x}$. Apply in the same way condoning slips

Alternatively attempts the quotient rule on $\mathrm{f}(x)=\dfrac{u}{v}=\dfrac{4\left(x^2-2\right)}{\mathrm{e}^{2x}}$ with $v'=k\mathrm{e}^{2x}$ and $\mathrm{f}'(x)=\dfrac{vu'-uv'}{v^2}$

A1: A correct $\mathrm{f}'(x)$ which may be unsimplified.

Via the quotient rule you can award for $\mathrm{f}'(x)=\dfrac{8x\mathrm{e}^{2x}-8\left(x^2-2\right)\mathrm{e}^{2x}}{\mathrm{e}^{4x}}$ o.e.

A1*: Proceeds correctly to given answer showing all necessary steps.

The $\mathrm{f}'(x)$ or $\dfrac{\mathrm{d}y}{\mathrm{d}x}$ must be present at some point in the solution

This is a "show that" question and there must not be any errors. All bracketing must be correct.

Allow a candidate to move from the **simplified** unfactorised answer of $\mathrm{f}'(x)=8x\mathrm{e}^{-2x}-8\left(x^2-2\right)\mathrm{e}^{-2x}$

to the given answer in one step.

Do not allow it from an **unsimplified** $f'(x) = 4\times 2xe^{-2x} + 4\left(x^2-2\right)\times -2e^{-2x}$

Allow the expression / bracketed expression to be written in a different order.

So, for example, $8\left(x - x^2 + 2\right)e^{-2x}$ is OK

(b)

B1: States or implies $x = -1, 2$ (as the roots of $f'(x) = 0$)

M1: Substitutes one x value of their solution to $f'(x) = 0$ in f(x) to find a y value.

Allow decimals here (3sf). FYI, to 3 sf, $-4e^2 = -29.6$ and $8e^{-4} = 0.147$

Some candidates just write down the x coordinates but then go on in part (c) to find the ranges using the y coordinates. Allow this mark to be scored from work in part (c)

A1: Obtains $\left(-1, -4e^2\right)$ and $\left(2, 8e^{-4}\right)$ as the stationary points. This must be scored in (b). Remember to isw after a correct answer. Allow these to be written separately. E.g. $x = -1,\ y = -4e^2$

Extra solutions, e.g. from $x = 0$ will be penalised on this mark.

(c)(i)

B1ft: For a correct range written using correct notation.

Follow through on 2 $\times$ their minimum "y" value from part (b), providing it is negative.

Condone a decimal answer if this is consistent with their answer in (b) to 3sf or better.

Examples of correct responses are $\left[-8e^2, \infty\right)$, $g \geqslant -8e^2$, $y \geqslant -8e^2$, $\left\{q \in \mathbb{R}, q \geqslant -8e^2\right\}$

(c)(ii)

M1: See main scheme. Follow through on $2\times$ their "$8e^{-4}$" -3 for the upper bound.

A1: Range $\left[-19, 16e^{-4} - 3\right]$ o.e. such as $-19 \leqslant y \leqslant 16e^{-4} - 3$ but must be exact