1 **(i)**	trials of at calculating f(x) for at least one factor of 30 details of calculation for f(2) or f(−3) or f(−5) attempt at division by (x − 2) as far as $x^3 - 2x^2$ in working correctly obtaining $x^2 + 8x + 15$ factorising a correct quadratic factor (x – 2)(x + 3)(x + 5)	**M1** **A1** **M1** **A1** **M1** **A1**	**M0** for division or inspection used or equiv for (x + 3) or (x + 5); or inspection with at least two terms of quadratic factor correct or B2 for another factor found by factor theorem for factors giving two terms of quadratic correct; M0 for formula without factors found condone omission of first factor found; ignore '= 0' seen allow last four marks for (x – 2)(x + 3)(x + 5) obtained; for all 6 marks must see factor theorem use first
1 **(ii)**	sketch of cubic right way up, with two turning points values of intns on x axis shown, correct (–5, –3, and 2) or ft from their factors/ roots in (i) y-axis intersection at −30	**B1** **B1** **B1**	0 if stops at x-axis on graph or nearby in this part mark intent for intersections with both axes or x = 0, y = −30 seen in this part if consistent with graph drawn

1 (iii)	$(x-1)$ substituted for x in either form of eqn for $y = f(x)$	**M1**	correct or ft their (i) or (ii) for factorised form; condone one error; allow for new roots stated as −4,−2 and 3 or ft
	$(x-1)^3$ expanded correctly (need not be simplified) or two of their factors multiplied correctly	**M1 dep**	or **M1** for correct or correct ft multiplying out of all 3 brackets at once, condoning one error [$x^3 - 3x^2 + x^2 + 2x^2 + 8x - 6x - 12x - 24$]
	correct completion to given answer [condone omission of 'y =']	**M1**	unless all 3 brackets already expanded, must show at least one further interim step allow **SC1** for $(x+1)$ subst <u>and</u> correct exp of $(x+1)^3$ or two of their factors ft <u>or</u>, for those using given answer: **M1** for roots stated or used as −4,−2 and 3 or ft **A1** for showing all 3 roots satisfy given eqn **B1** for comment re coefft of x^3 or product of roots to show that eqn of translated graph is not a multiple of RHS of given eqn

2	(i)	cubic correct way up and with two turning pts	**B1**	
		touching x-axis at −1, and through it at 2.5 and no other intersections	**B1**	intns must be shown labelled or worked out nearby
		y- axis intersection at −5	**B1**	
2	(ii)	$2x^3 - x^2 - 8x - 5$	**2**	**B** for 3 terms correct or **M1** for correct expansion of product of two of the given factors

3	iA	expansion of one pair of brackets	M1	eg $[(x + 1)](x^2 - 6x + 8)$; need not be simplified	
		correct 6 term expansion	M1	eg $x^3 - 6x^2 + 8x + x^2 - 6x + 8$; or M2 for correct 8 term expansion: $x^3 - 4x^2 + x^2 - 2x^2 + 8x - 4x - 2x + 8$, M1 if one error allow equivalent marks working backwards to factorisation, by long division or factor theorem etc or M1 for all three roots checked by factor theorem and M1 for comparing coeffts of x^3	2
	iB	cubic the correct way up x-axis: −1, 2, 4 shown y-axis 8 shown	G1 G1 G1	with two tps and extending beyond the axes at 'ends' ignore a second graph which is a translation of the correct graph	3

	iC	[y=]$(x-2)(x-5)(x-7)$ isw or $(x-3)^3-5(x-3)^2+2(x-3)+8$ isw or $x^3-14x^2+59x-70$	2	M1 if one slip or for [y =] f(x − 3) or for roots identified at 2, 5, 7 or for translation 3 to the left allow M1 for complete attempt: $(x+4)(x+1)(x-1)$ isw or $(x+3)^3-5(x+3)^2+2(x+3)+8$ isw	
		$(0, -70)$ or $y=-70$	1	allow 1 for $(0, -4)$ or $y=-4$ after f(x + 3) used	3
	ii	$27-45+6+8=-4$ or $27-45+6+12=0$	B1	or correct long division of $x^3-5x^2+2x+12$ by $(x-3)$ with no remainder or of x^3-5x^2+2x+8 with rem −4	
		long division of f(x) or their f(x) + 4 by $(x-3)$ attempted as far as x^3-3x^2 in working	M1	or inspection with two terms correct eg $(x-3)(x^2$ ....$-4)$	
		x^2-2x-4 obtained	A1		
		$[x=]\dfrac{2\pm\sqrt{(-2)^2-4\times(-4)}}{2}$ or $(x-1)^2=5$	M1	dep on previous M1 earned; for attempt at formula or comp square on their other 'factor'	
		$\dfrac{2\pm\sqrt{20}}{2}$ o.e. isw or $1\pm\sqrt{5}$	A1		5 13

4		f(−4) used	M1		
		−128 + 112 + 28 − 12 [= 0]	A1	or B2 for $(x + 4)(2x^2 - x - 3)$ here; or correct division with no remainder	2
	ii	division of f(x) by (x + 4)	M1	as far as $2x^3 + 8x^2$ in working, or two terms of $2x^2 - x - 3$ obtained by inspection etc (may be earned in (i)), or f(−1) = 0 found	
		$2x^2 - x - 3$	A1	$2x^2 - x - 3$ seen implies M1A1	
		$(x + 1)(2x - 3)$	A1		
		[f(x) =] $(x + 4)(x + 1)(2x - 3)$	A1	or B4; allow final A1 ft their factors if M1A1A0 earned	4
	iii	sketch of cubic correct way up	G1	ignore any graph of $y = f(x - 4)$	
		through −12 shown on y axis	G1	or coords stated near graph	
		roots −4, −1, 1.5 or ft shown on x axis	G1	or coords stated near graph if no curve drawn, but intercepts marked on axes, can earn max of G0G1G1	3
	iv	$x(x - 3)(2[x - 4] - 3)$ o.e. or $x(x - 3)(x - 5.5)$ or ft their factors	M1	or $2(x - 4)^3 + 7(x - 4)^2 - 7(x - 4) - 12$ or stating roots are 0, 3 and 5.5 or ft; condone one error eg $2x - 7$ not $2x - 11$	
		correct expansion of one pair of brackets ft from their factors	M1	or for correct expn of $(x - 4)^3$ [allow unsimplified]; or for showing g(0) = g(3) = g(5.5) = 0 in given ans g(x)	
		correct completion to given answer	M1	allow M2 for working backwards from given answer to $x(x - 3)(2x - 11)$ and M1 for full completion with factors or roots	3

12

5	**i**	$2x^3 + 5x^2 + 4x - 6x^2 - 15x - 12$	1	for correct interim step; allow correct long division of f(x) by ($x - 3$) to obtain $2x^2 + 5x + 4$ with no remainder	
		3 is root	B1	allow f(3) = 0 shown	
		use of $b^2 - 4ac$	M1	or equivalents for M1 and A1 using	
		$5^2 - 4 \times 2 \times 4$ or -7 and [negative] implies no real root	A1	formula or completing square	4
	ii	divn of f(x) + 22 by $x - 2$ as far as $2x^3 - 4x^2$ used	M1	or inspection eg $(x - 2)(2x^2 \ldots\ldots -5)$	
		$2x^2 + 3x - 5$ obtained	A1		
		$(2x + 5)(x - 1)$	M1	attempt at factorising/quad. formula/	
		1 and −2.5 o.e.	A1 +A	compl. sq.	
		<u>or</u>			
		$2 \times 2^3 - 2^2 - 11 \times 2 - 12$	M1	<u>or</u> equivs using f(x) + 22	
		$16 - 4 - 22 - 12$	A1		
		$x = 1$ is a root obtained by factor thm	B1	not just stated	
		$x = -2.5$ obtained as root	B2		5
	iii	cubic right way up	G1	must have turning points	
		crossing x axis only once	G1	must have max and min below x axis	
		(3, 0) and (0, −12) shown	G1	at intns with axes or in working (indep of cubic shape); ignore other intns	3