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**Level: 100lvl**

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$$\int \frac{(3x-1) dx}{(x+1)(x-2)(x-3)} = \frac{A}{x+1} + \frac{B}{x-2} + \frac{C}{x-3}$$

$$\frac{(3x-1)(x-2)(x-3)}{(x+1)(x-2)(x-3)} = \frac{A(x-2)(x-3)}{(x+1)} + \frac{B(x+1)(x-3)}{(x-2)} + \frac{C(x+1)(x-2)}{(x-3)}$$

$3x-1 = A(x-2)(x-3) + B(x-2)(x-3) + C(x-1)(x-2)$   
 $3x-1 = A(x^2-5x+6) + B(x^2-5x+6) + C(x^2-3x+2)$   
 $3x-1 = x^2(A+B+C) + x(-5A-5B-3C) + (6A+6B+2C)$

Compare LHS to the RHS

$A+B+C = 0 \dots \text{--- (1)}$   
 $-5A-5B-3C = 3 \dots \text{--- (2)}$   
 $6A+6B+2C = -1 \dots \text{--- (3)}$

$A = -B - C \dots \text{--- (4)}$  (Subst into eqn (2))  
 $-5(-B-C) - 5B - 3C = 3$   
 $5B + 5C - 5B - 3C = 3$   
 $2C = 3$   
 $C = \frac{3}{2}$

$B = 3 - 2C \dots \text{--- (5)}$  (Subst into eqn (1))  
 $B = 3 - 2(\frac{3}{2})$   
 $B = 3 - 3$   
 $B = 0$

$A = -B - C$   
 $A = -0 - \frac{3}{2}$   
 $A = -\frac{3}{2}$

$\int \frac{(3x-1) dx}{(x+1)(x-2)(x-3)} = \frac{-\frac{3}{2}}{x+1} + \frac{0}{x-2} + \frac{\frac{3}{2}}{x-3}$   
 $= \frac{-3}{2(x+1)} + \frac{3}{2(x-3)} + \ln|(x-3)| + C$

3)  $\int \frac{(x^2+x+1) dx}{(x+1)(x^2+1)} = \frac{A}{x+1} + \frac{Bx+C}{x^2+1}$

$\frac{(x^2+x+1)(x^2+1)}{(x+1)(x^2+1)} = \frac{A(x^2+1)}{(x+1)} + \frac{(Bx+C)(x+1)}{(x^2+1)}$   
 $x^2+x+1 = A(x+1) + (Bx+C)(x+1)$   
 $x^2+x+1 = Ax^2 + Ax + Bx^2 + Bx + Cx + C$   
 $x^2+x+1 = (A+B)x^2 + (A+B)x + C$

$A+B = 1 \dots \text{--- (1)}$   
 $A+B = 1$   
 $-4A - 5B + C = 0 \dots \text{--- (2)}$   
 $-4A - 5B + C = 0$   
 $4A + 6B - 3C = 1 \dots \text{--- (3)}$   
 $4A + 6B - 3C = 1$   
 $A = 1 - B \dots \text{--- (4)}$   
 $A = 1 - B$

$4(1-B) - 5B + C = 0$   
 $4 - 4B - 5B + C = 0$   
 $4 - 9B + C = 0$   
 $C = 9B - 4$

$4A + 6B - 3C = 1$   
 $4(1-B) + 6B - 3(9B-4) = 1$   
 $4 - 4B + 6B - 27B + 12 = 1$   
 $16 - 25B = 1$   
 $-25B = 1 - 16$   
 $-25B = -15$   
 $B = \frac{15}{25} = \frac{3}{5}$

$A = 1 - B = 1 - \frac{3}{5} = \frac{2}{5}$   
 $C = 9B - 4 = 9(\frac{3}{5}) - 4 = \frac{27}{5} - 4 = \frac{27-20}{5} = \frac{7}{5}$

$\int \frac{(x^2+x+1) dx}{(x+1)(x^2+1)} = \frac{\frac{2}{5}}{x+1} + \frac{\frac{3}{5}x + \frac{7}{5}}{x^2+1}$   
 $= \frac{2}{5(x+1)} + \frac{3x}{5(x^2+1)} + \frac{7}{5(x^2+1)} + C$

$x^2+x+1 = x^2(A+B) + x(B+C) + A + 2C$   
 $A+B = 1 \dots \text{--- (1)}$   
 $2B+C = 1 \dots \text{--- (2)}$   
 $A+2C = 1 \dots \text{--- (3)}$

$A = 1 - B \dots \text{--- (4)}$   
 $A = 1 - B$   
 $4A + 6B - 3C = 1$   
 $4(1-B) + 6B - 3C = 1$   
 $4 - 4B + 6B - 3C = 1$   
 $4 + 2B - 3C = 1$   
 $2B - 3C = 1 - 4$   
 $2B - 3C = -3$   
 $2B = 3 - 3C$   
 $B = \frac{3-3C}{2}$

$A = 1 - B = 1 - \frac{3-3C}{2} = \frac{2-3+3C}{2} = \frac{-1+3C}{2}$

$2B + C = 1$   
 $2(\frac{3-3C}{2}) + C = 1$   
 $3 - 3C + C = 1$   
 $3 - 2C = 1$   
 $-2C = 1 - 3$   
 $-2C = -2$   
 $C = 1$

$B = \frac{3-3(1)}{2} = \frac{3-3}{2} = 0$   
 $A = \frac{-1+3(1)}{2} = \frac{-1+3}{2} = \frac{2}{2} = 1$

$\int \frac{(x^2+x+1) dx}{(x+1)(x^2+1)} = \frac{1}{x+1} + \frac{0x+1}{x^2+1}$   
 $= \frac{1}{x+1} + \frac{1}{x^2+1} + C$

3)  $\int \frac{(x^2+1) dx}{(x-1)(x-2)(x-3)} = \frac{A}{x-1} + \frac{B}{x-2} + \frac{C}{x-3}$

$\frac{(x^2+1)(x-2)(x-3)}{(x-1)(x-2)(x-3)} = \frac{A(x-2)(x-3)}{(x-1)} + \frac{B(x-1)(x-3)}{(x-2)} + \frac{C(x-1)(x-2)}{(x-3)}$   
 $x^2+1 = A(x-2)(x-3) + B(x-1)(x-3) + C(x-1)(x-2)$   
 $x^2+1 = A(x^2-5x+6) + B(x^2-4x+3) + C(x^2-3x+2)$   
 $x^2+1 = x^2(A+B+C) + x(-5A-4B-3C) + (6A+3B+2C)$

$A+B+C = 1 \dots \text{--- (1)}$   
 $-5A-4B-3C = 0 \dots \text{--- (2)}$   
 $6A+3B+2C = 1 \dots \text{--- (3)}$

$A = 1 - B - C \dots \text{--- (4)}$  (Subst into eqn (2))  
 $-5(1-B-C) - 4B - 3C = 0$   
 $-5 + 5B + 5C - 4B - 3C = 0$   
 $B + 2C = 5$

$B = 5 - 2C \dots \text{--- (5)}$  (Subst into eqn (3))  
 $6A + 3(5-2C) + 2C = 1$   
 $6A + 15 - 6C + 2C = 1$   
 $6A - 4C = 1 - 15$   
 $6A - 4C = -14$   
 $3A - 2C = -7$   
 $3A = 7 - 2C$   
 $A = \frac{7-2C}{3}$

$B = 5 - 2C$   
 $A = \frac{7-2C}{3}$

$\int \frac{(x^2+1) dx}{(x-1)(x-2)(x-3)} = \frac{\frac{7-2C}{3}}{x-1} + \frac{5-2C}{x-2} + \frac{C}{x-3}$   
 $= \frac{7-2C}{3(x-1)} + \frac{5-2C}{x-2} + \frac{C}{x-3} + C$

$$\int \frac{(x^2+1)}{(x-3)(x-2)^2} dx = \int \frac{10}{x-3} - \int \frac{9}{x-2} - \int \frac{5}{(x-2)^2}$$

$$u = x-2$$

$$\frac{du}{dx} = 1 = 10 \ln(x-3) - 9 \ln(x-2) - 5 \int (u^{-2}) du$$

$$du = dx = 10 \ln(x-3) - 9 \ln(x-2) - 5 \ln(x-2)^{-1} + C$$

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$$\int (2x^2 + 3x + 1)$$

$$= x^{-1} \int \frac{x^2 + 3x + 3}{x^2 - x^2 + x + 1}$$

$$= x^{-1} \int \frac{x^2 + x^2 + x + 1}{x^2 - x^2 + x + 1}$$

$$= \frac{2x^2 + x + 1}{x^2 - x^2 + x + 1}$$

$$= \frac{2x^2 - 2x}{x^2 - x^2 + x + 1}$$

$$= \frac{2x(x-1)}{x^2 - x^2 + x + 1}$$

$$= \frac{2x(x-1)}{x^2 - x^2 + x + 1}$$

$$= \frac{2x(x-1)}{x^2 - x^2 + x + 1}$$

$$\int (3x^2 + 2x + 3) dx + \int \frac{2}{x-1} dx$$

$$= \frac{3x^3}{3} + \frac{2x^2}{2} + 3x + 2 \ln|x-1| + C$$

$$= x^3 + x^2 + 3x + 2 \ln|x-1| + C$$

$$= x^3 + x^2 + 3x + 2 \ln|x-1| + C$$