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Exe 3.5

PARTIAL FRACTION

Type 1 : When Power of x is Linear
(Linear) (Linear).

$$\frac{1}{(x+3)(x+4)} = \frac{A}{x+3} + \frac{B}{x+2}$$

Type II : When whole power of x is involve
(Linear) (Linear Repeated)

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

Type III : When self power of x is involve.
(Linear) (Quadratic)

$$\frac{1}{(x+3)(x^2+4)} = \frac{A}{x+3} + \frac{Bx+C}{(x^2+4)}$$

Type IV : When whole power of x (self Power) is Involved.
(Linear) (Quadratic Repeated)

$$\frac{1}{(x+3)(x^2+4)^2} = \frac{A}{x+3} + \frac{Bx+C}{x^2+4} + \frac{Dx+E}{(x^2+4)^2}$$

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Rule 1: (Power Rule)

$$\int [f(x)]^n f'(x)\,dx = \frac{[f(x)]^{n+1}}{n+1} + c$$

Rule II:

$$\int \frac{f'(x)}{f(x)}\,dx = \ln|f(x)| + c$$

Q#1 $\int \frac{3x+7}{(x+2)(x+3)}\,dx$

Sol First we find Partial Fraction:

Consider

$$\frac{3x+7}{(x+2)(x+3)} = \frac{A}{x+2} + \frac{B}{x+3} \quad \text{——— (i)}$$

xing b. side by $(x+2)(x+3)$

$$\frac{3x+7}{\cancel{(x+2)(x+3)}} \times (x+2)(x+3) = \frac{A}{\cancel{x+2}} \times \cancel{(x+2)}(x+3) + \frac{B}{\cancel{x+3}} \times (x+2)\cancel{(x+3)}$$

$$3x+7 = A(x+3) + B(x+2) \quad \text{——— (ii)}$$

Put $x+2=0$

$x=-2$

Put $x=-2$ in (ii)

$3(-2)+7 = A(-2+3) + B(0)$

$-6+7 = A(1)$

$1 = A$ $\boxed{A=1}$

Put $x+3=0$

$x = -3$

Put in (ii)

$3(-3)+7 = A(0) + B(-3+2)$

$-9+7 = -B$

$\cancel{-}2 = \cancel{-}B$

$\boxed{B=2}$

Put values of A and B in (i)

$$\frac{3x+7}{(x+2)(x+3)} = \frac{A}{x+2} + \frac{B}{x+3}$$

$$\frac{3x+7}{(x+2)(x+3)} = \frac{1}{x+2} + \frac{2}{x+3}$$

Integrating b.sides

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

$$= \int \frac{1}{x+2}\,dx + 2\int \frac{1}{x+3}\,dx \qquad \text{Rule II}$$

$$\int \frac{3x+7}{(x+2)(x+3)}\,dx = \ln|x+2| + 2\ln|x+3| + C$$

Q#2. $\int \frac{4x+9}{x^2+x-12}\,dx$

Sol. First we find Partial Fraction

Consider

$$\frac{4x+9}{x^2+x-12} = \frac{4x+9}{x^2+4x-3x-12} = \frac{4x+9}{x(x+4)-3(x+4)}$$

$$\Rightarrow \frac{4x+9}{(x+4)(x-3)} = \frac{A}{x+4} + \frac{B}{x-3} \quad \text{—— (i)}$$

xing b.side by $(x+4)(x-3)$

$$4x+9 = A(x-3) + B(x+4) \quad \text{—— (ii)}$$

Put $x+4=0$

$x=-4$

$4(-4)+9 = A(-4-3) + B(0)$

$-16+9 = -7A$

$\frac{-7}{-7} = A \qquad \boxed{A=1}$

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Put $x - 3 = 0$

$x = 3$

$4(3) + 9 = A(0) + B(3+4)$

$21 = 7B$

$\frac{21}{7} = B$

$\boxed{B = 3}$

Put values of A and B in (1)

$$\frac{4x+9}{(x+4)(x-3)} = \frac{1}{x+4} + \frac{3}{x-3}$$

Integrating b. sides

$$\int \frac{4x+9}{(x+4)(x-3)}\,dx = \int \frac{1}{x+4}\,dx + 3\int \frac{1}{x-3}\,dx$$

Rule II

$$\int \frac{4x+9}{(x+4)(x-3)}\,dx = \ln|x+4| + 3\ln|x-3| + C$$

Q#3 $\int \frac{21-8x}{x^2+x-6}\,dx$

Sol First we Find Partial Fraction

Consider

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$$= \frac{21-8x}{x^2+x-6} = \frac{21-8x}{x^2+3x-2x-6} = \frac{21-8x}{x(x+3)-2(x+3)}$$

$$= \frac{21-8x}{(x+3)(x-2)} = \frac{A}{x+3} + \frac{B}{x-2} \quad \text{--- (i)}$$

Xing b.side by $(x+3)(x-2)$

$$\Rightarrow 21-8x = A(x-2) + B(x+3) \quad \text{--- (ii)}$$

Put $x+3=0$

$x=-3$

$$21-8(-3) = A(-3-2) + B(0)$$

$$21+24 = A(-5)$$

$$\frac{45}{-5} = A$$

$$\boxed{A=-9}$$

Put $x-2=0$ $\quad x=2$

$$21-8(2) = A(0) + B(2+3)$$

$$21-16 = 5B$$

$$\frac{5}{5} = B$$

$$\boxed{B=1}$$

Put values of A and B in (i)

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$$\frac{21-8x}{(x+3)(x-2)} = \frac{-9}{x+3} + \frac{1}{x-2}$$

Integrating b. sides

$$\int \frac{21-8x}{(x+3)(x-2)}\,dx = -9\int \frac{1}{x+3}\,dx + \int \frac{1}{x-2}\,dx$$

Rule II.

$$= -9.\ Ln|x+3| + Ln|x-2| + C$$

Q #4 $\int \frac{3x+7}{(x+2)^2}\,dx$

Sol. First we Find Partial Fraction
Consider

$$\frac{3x+7}{(x+2)^2} = \frac{A}{x+2} + \frac{B}{(x+2)^2} \quad \text{——(i)}$$

Xing b. side by $(x+2)^2$

$$3x+7 = A(x+2) + B \quad \text{——(ii)}$$

$$3x+7 = Ax + 2A + B \quad \text{——(iii)}$$

Put $x+2=0$

$x = -2$

$3(-2)+7 = A(0) + B$

$-6+7 = B$

$\boxed{B = 1}$

Compare the coeff of x eq (iii)

$3 = A \qquad \boxed{A = 3}$

Put the values of A and B in (i)

$$\frac{3x+7}{(x+2)^2} = \frac{3}{x+2} + \frac{1}{(x+2)^2}$$

Integrating b.sides

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

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

Rule II Rule I

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

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

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Q#5 $\int \frac{5x^2-5x+2}{(x+1)(x-1)^2}\,dx$

Sol: First we find Partial fraction
Consider

$$\frac{5x^2-5x+2}{(x+1)(x-1)^2} = \frac{A}{x+1} + \frac{B}{x-1} + \frac{C}{(x-1)^2} \quad \text{---(1)}$$

xing b. side by $(x+1)(x-1)^2$

$$5x^2-5x+2 = A(x-1)^2 + B(x+1)(x-1) + C(x+1) \quad \text{---(2)}$$

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

$$5x^2-5x+2 = Ax^2-2Ax+A+Bx^2-B+Cx+C \quad \text{---(3)}$$

• Put $x+1=0$
$x=-1$

$$5(-1)^2-5(-1)+2 = A(-1-1)^2 + B(0) + C(0)$$

$$5+5+2 = A(4)$$

$$\frac{12}{4} = A$$

$$\boxed{A=3}$$

• Put $x-1=0$
$x=1$

$$5(1)^2 - 5(1) + 2 = A(0) + B(0) + C(1+1)$$

$$8 - 8 + 2 = 2C$$

$$\frac{2}{2} = C$$

$$\boxed{C = 1}$$

Compare coff of x^2

$$5 = A + B$$

$$5 - 3 = B$$

$$\boxed{B = 2}$$

Put the values of A, B and C in (1)

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

Integrating b. sides

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

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

Rule II   Rule II   Rule I

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

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

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Q#6 $\int \frac{9x^2+3x+29}{(x+1)(x^2+4)}\,dx$

Sol: First we find Partial Fraction

Consider.

$$\frac{9x^2+3x+29}{(x+1)(x^2+4)} = \frac{A}{x+1} + \frac{Bx+C}{x^2+4} \quad \text{—(i)}$$

xing b. side by $(x+1)(x^2+4)$

$$9x^2+3x+29 = A(x^2+4) + Bx+C\,(x+1) \quad \text{—(2)}$$

$$9x^2+3x+29 = Ax^2+4A+Bx^2+Bx+Cx+C \quad \text{—(3)}$$

Put $x+1=0$

$x=-1$

$$9(-1)^2+3(-1)+29 = A(1+4)+0$$

$$9-3+29 = 5A$$

$$\frac{35}{5} = A$$

$$\boxed{A=7}$$

From (3) compare coeff of x^2

$$9 = A+B$$

$$9-7 = B \qquad \boxed{B=2}$$

Compare Coeff of x

$$3 = B + C$$

$$3 - 2 = C$$

$$\boxed{C = 1}$$

Put the values of A, B, C in (i)

$$\frac{9x^2+3x+29}{(x+1)(x^2+4)} = \frac{7}{x+1} + \frac{2x+1}{x^2+4}$$

Integrating b.sides

$$\int \frac{9x^2+3x+29}{(x+1)(x^2+4)}\,dx = \int \frac{7}{x+1}\,dx + \int \frac{2x+1}{x^2+4}\,dx$$

$$= 7\int \frac{1}{x+1}\,dx + \int \frac{2x}{x^2+4}\,dx + \int \frac{1}{x^2+2^2}\,dx$$

$$= \quad \int \frac{1}{a^2+x^2}\,dx = \frac{1}{a}\tan^{-1}\left(\frac{x}{a}\right) + C$$

$$= 7\ln|x+1| + \ln|x^2+4| + \frac{1}{2}\tan^{-1}\left(\frac{x}{2}\right) + C$$

Ans.

(7) $$\int \frac{7x^2+7x+4}{(2x+1)(x^2+x+1)}\,dx$$

Sol First we find Partial Fraction

Consider

$$\frac{7x^2+7x+4}{(2x+1)(x^2+x+1)} = \frac{A}{2x+1} + \frac{Bx+C}{x^2+x+1} \quad \text{—(i)}$$

xing b. side by $(2x+1)(x^2+x+1)$

$$7x^2+7x+4 = A(x^2+x+1) + Bx+C\,(2x+1) \quad \text{—(2)}$$

$$7x^2+7x+4 = Ax^2+Ax+A+2Bx^2+Bx+2Cx+C \text{ —}$$

Put $2x+1=0$

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

Put $x = \frac{-1}{2}$ in (2)

$$7\left(\frac{-1}{2}\right)^2 + 7\left(\frac{-1}{2}\right)+4 = A\left(\left(\frac{-1}{2}\right)^2 - \frac{1}{2}+1\right) + 0$$

$$\frac{7}{4} - \frac{7}{2} + \frac{4}{1} = A\left(\frac{1}{4} - \frac{1}{2} + 1\right)$$

$$\frac{7-14+16}{4} = A\left(\frac{1-2+4}{4}\right)$$

$$\frac{9}{4} = A\left(\frac{3}{4}\right)$$

$$\frac{9}{4} \times \frac{4}{3} = A$$

$$\boxed{A = 3}$$

Compare the coeff of x^2

$$7 = A + 2B$$
$$7 = 3 + 2B$$
$$7 - 3 = 2B$$
$$B = \frac{4}{2}$$
$$\boxed{B = 2}$$

Compare the coeff of x

$$7 = A + B + 2C$$
$$7 = 3 + 2 + 2C$$
$$7 - 5 = 2C$$
$$\boxed{C = 1}$$

Put the values of A, B, C in (i)

$$\frac{7x^2+7x+4}{(2x+1)(x^2+x+1)} = \frac{3}{2x+1} + \frac{2x+1}{x^2+x+1}$$

Integrating b. sides:

$$\int \frac{7x^2+7x+4}{(2x+1)(x^2+x+1)}\,dx = 3\int \frac{1}{2x+1}\,dx + \int \frac{2x+1}{x^2+x+1}\,dx$$

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

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$$= \frac{3}{2} \ln|2x+1| + \ln|x^2+x+1| + C \quad \text{An.}$$

(8) $\int \frac{x^3+4x^2+9x+14}{x^2+4x+3}\,dx$ (Improper Form)

Sol: First we find Partial Fraction

Consider

$$\frac{x^3+4x^2+9x+14}{x^2+4x+3}$$

It is improper Fraction so first we divide it.

$$\begin{array}{r|l} & x \\ x^2+4x+3 & \cancel{x^3}+\cancel{4x^2}+9x+14 \\ & \pm \cancel{x^3} \pm \cancel{4x^2} \pm 3x \\ \hline & 6x+14 \end{array}$$

So

$$\frac{x^3+4x^2+9x+14}{x^2+4x+3} = x + \frac{6x+14}{x^2+4x+3} \quad \text{—— (A)}$$

Now

$$\frac{6x+14}{x^2+4x+3} = \frac{6x+14}{x^2+3x+x+3} = \frac{6x+14}{x(x+3)+1(x+3)}$$

$$\frac{6x+14}{(x+1)(x+3)} = \frac{A}{x+1} + \frac{B}{x+3} \quad \text{—— (i)}$$

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Xing b. side by $(x+1)(x+3)$

$6x+14 = A(x+3) + B(x+1)$ —— (2)

Put $x+1=0 \Rightarrow x=-1$

$6(-1)+14 = A(-1+3)$

$-6+14 = 2A$

$\frac{8}{2} = A$

$\boxed{A=4}$

Put $x+3=0 \Rightarrow x=-3$

$6(-3)+14 = 0 + B(-3+1)$

$-18+14 = -2B$

$\frac{-4}{-2} = B$

$\boxed{B=2}$

Put the value of A and B in (i)

$$\frac{6x+14}{(x+1)(x+3)} = \frac{4}{x+1} + \frac{2}{x+3}$$

Now Eq # (A) becomes.

$$\frac{x^3+4x^2+9x+14}{x^2+4x+3} = x + \frac{4}{x+1} + \frac{2}{x+3}$$

Integrating b. sides

$$\int \frac{x^3+4x^2+9x+14}{x^2+4x+3}\,dx = \int x\,dx + 4\int \frac{1}{x+1}\,dx + 2\int \frac{1}{x+3}\,dx$$

$$= \frac{x^2}{2} + 4\ln|x+1| + 2\ln|x+3| \quad \text{Ans}$$

(9) $\int \frac{1}{x^2+9}\,dx$

Sol First we find Partial Fraction

Consider:

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

$$\frac{1}{(x+3)(x-3)} = \frac{A}{x+3} + \frac{B}{x-3} \quad \text{--- (1)}$$

xing b. side by $(x+3)(x-3)$

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

Put $x+3=0 \Rightarrow x=-3$

$$1 = A(-3-3) + B(0)$$

$$\boxed{A = \frac{-1}{6}}$$

Put $x-3=0 \Rightarrow x=3$

$$1 = A(3-3) + B(3+3)$$

$$1 = 6B$$

$$\boxed{B = \frac{1}{6}}$$

Put the values of A and B in (1)

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$$\frac{1}{(x+3)(x-3)} = \frac{-1}{6(x+3)} + \frac{1}{6(x-3)}$$

Integrating:

$$\int \frac{1}{x^2+9}\,dx = \frac{-1}{6}\int \frac{1}{x+3}\,dx + \frac{1}{6}\int \frac{1}{x-3}\,dx$$

$$= \frac{-1}{6}\ln|x+3| + \frac{1}{6}\ln|x-3| + C \quad \text{Ans}$$

(10) $\displaystyle\int \frac{1}{x^3+2x^2+x}\,dx$

Sol $\displaystyle\int \frac{1}{x(x^2+2x+1)}\,dx$

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

First we find Partial fraction

Consider:

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

xing b. side by $x(x+1)^2$

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

$$1 = Ax^2 + 2Ax + A + Bx^2 + Bx + Cx \quad \text{---(3)}$$

Put $x=0$

$$1 = A(0+1)^2 + 0 + 0$$

$$1 = A(1)$$

$$\boxed{A=1}$$

Put $x+1=0 \Rightarrow x=-1$

$$1 = 0 + 0 + C(-1)$$

$$\boxed{C=-1}$$

From (3) Compare the Coeff of x^2

$$0 = A + B$$

$$B = -A$$

$$B = -(1) \qquad \boxed{B=-1}$$

Put the values of A, B, C in (i)

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

Integrating

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

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

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

$$= \ln|x| - \ln|x+1| + \frac{1}{(x+1)} + C \quad \text{Ans}$$

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

Sol

$$\text{Put } e^x = y$$

$$\frac{d}{dx} e^x = \frac{dy}{dx}$$

$$e^x = \frac{dy}{dx}$$

$$e^x dx = dy$$

$$\int \frac{1}{(y+1)^2 (y-2)} dy$$

First we find Partial Fraction.

Consider

$$\frac{1}{(y-2)(y+1)^2} = \frac{A}{y-2} + \frac{B}{y+1} + \frac{C}{(y+1)^2} \quad \text{---} (i)$$

Xing b. sides by $(y-2)(y+1)^2$

$1 = A(y+1)^2 + B(y-2)(y+1) + C(y-2)$ — (2)

$1 = Ay^2 + 2Ay + A + B(y^2 - 2y + y - 2) + Cy - 2C$

$1 = Ay^2 + 2Ay + A + By^2 - By - 2B + Cy - 2C$ — (3)

Put $y - 2 = 0$

$y = 2$

$1 = A(2+1)^2$

$\boxed{\frac{1}{9} = A}$

Put $y + 1 = 0$

$y = -1$

$1 = 0 + 0 + C(-1-2)$

$\boxed{C = \frac{-1}{3}}$

Compare the coeff of y^2

$0 = A + B$

$0 = \frac{1}{9} + B$

$\boxed{B = \frac{-1}{9}}$

Put the values of A, B, C in (i)

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$$\frac{1}{(y-2)(y+1)^2} = \frac{1}{9(y-2)} - \frac{1}{9(y+1)} - \frac{1}{3(y+1)^2}$$

Integrating.

$$\int \frac{1}{(y-2)(y+1)^2}\,dy = \frac{1}{9}\int \frac{1}{y-2}\,dy - \frac{1}{9}\int \frac{1}{y+1}\,dy - \frac{1}{3}\int \frac{1}{(y+1)^2}\,dy$$

$$= \frac{1}{9}\ln|y-2| - \frac{1}{9}\ln|y+1| - \frac{1}{3}\int (y+1)^{-2}\,dy$$

$$= \frac{1}{9}\ln|y-2| - \frac{1}{9}\ln|y+1| - \frac{1}{3}\frac{(y+1)^{-2+1}}{-2+1} + C$$

$$= \frac{1}{9}\ln|y-2| - \frac{1}{9}\ln|y+1| + \frac{1}{3(y+1)} + C \quad \text{Ans.}$$

$$= \frac{1}{9}\ln|e^x-2| - \frac{1}{9}\ln|e^x+1| + \frac{1}{3(e^x+1)} + C \quad \text{Ans}$$

(12) $\displaystyle\int \frac{x}{(x+1)^2(x^2+1)}\,dx$

Sol: First we find Partial fraction

$$\frac{x}{(x+1)^2(x^2+1)} = \frac{A}{x+1} + \frac{B}{(x+1)^2} + \frac{Cx+D}{x^2+1} \quad \text{---}(i)$$

xing b.sides by $(x+1)^2(x^2+1)$

$$x = A(x+1)(x^2+1) + B(x^2+1) + (Cx+D)(x+1)^2$$

$$x = A(x^3+x+x^2+1) + B(x^2+1) + (Cx+D)(x^2+2x+1)$$

$$x = Ax^3 + Ax + Ax^2 + A + Bx^2 + B + Cx^3 + 2Cx^2 + Cx + Dx^2 + 2D\ldots$$

Put $x+1=0$

$x=-1$

$$-1 = B(1+1)$$

$$\boxed{B = \frac{-1}{2}}$$

Compare coeff of x^3

$$0 = A + C \quad — (4)$$

Compare coeff of x^2

$$0 = A + B + D + 2C \quad — (5)$$

Compare coeff of x

$$1 = A + C + 2D \quad — (6)$$

Compare coeff of constant

$$0 = A + B + D \quad — (7)$$

Put eq (4) in (6)

$$1 = 0 + 2D$$

$$\boxed{D = \frac{1}{2}}$$

Put the values of B and D in (7)

$$0 = A - \frac{1}{2} + \frac{1}{2}$$

$$\boxed{A = 0}$$

Put $A = 0$ in (4)

$$0 = 0 + C$$

$$\boxed{C = 0}$$

Put the values of A, B, C, D in (1)

$$\frac{x}{(x+1)^2(x^2+1)} = \frac{0}{x+1} - \frac{1}{2(x+1)^2} + \frac{1}{2(x^2+1)}$$

Integrating

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

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

$$= \frac{-1}{2}\,\frac{(x+1)^{-2+1}}{-2+1} + \frac{1}{2}\cdot\frac{1}{1}\tan^{-1}\left(\frac{x}{1}\right) + C$$

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

Complete

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