# MATHEMATICS

## ASSIGNMENT-2

Q1) $\frac{d^2y}{dx^2} - 4\frac{dy}{dx} + 4y = 8x^2 e^{2x} \sin 2x$

A $(D^2 - 4D + 4)y = 8x^2 e^{2x} \sin 2x$

$D^2 - 4D + 4 = 0$

$D(D-2) - 2(D-2) = 0$

$D = 2, 2$

$CF = e^{2x}(C_1 + C_2 x)$

$PI = \frac{1}{(D^2-4D+4)} 8x^2 e^{2x} \sin 2x$

$= \frac{8e^{2x}}{D^2 + \cancel{4D} + 4 - \cancel{4D} - 8 + 4} x^2 \sin 2x$

$\Rightarrow 8e^{2x} \frac{1}{D^2} x^2 \sin 2x$

$= 8e^{2x} \frac{1}{D}\left[-\frac{1}{2}x^2 \cos(2x) + \frac{1}{2}x \sin(2x) + \frac{1}{4}\cos(2x) + C\right]$

$\Rightarrow 8e^{2x}\left[-\frac{1}{4}x^2 \sin(2x) - \frac{1}{4}x\cos(2x) + \frac{1}{8}\sin(2x) + \frac{1}{8}\sin(2x) + \frac{1}{8}\sin 2x + C_1\right]$

$\Rightarrow e^{2x}(-2x^2 \sin(2x) - 2x\cos(2x) + 3\sin(2x) + C]$

$y = CF + PI$

$= e^{2x}(C_1 + C_2 x) + e^{2x}[-2x^2 \sin 2x - 2x\cos 2x + 3\sin 2x]$ ~~+C~~

Q2) $D^2x + Dy + 3x = e^{-t}$ — ①
$D^2y - 4Dx + 3y = \sin 2t$ — ②

multiply eq ① by $(D^2+3)$ & ② by D

$(D^2+3)^2x + D(D^2+3)y = (D^2+3)e^{-t}$ — ③
$-4D^2x + D(D^2+3)y = (\sin 2t)(D)$ — ④

On subtracting

$(D^2+3)^2x + D(D^2+3)y + 4D^2x - D(D^2+3)y = e^{-t}(D^2+3) - D(\sin 2t)$

$(D^4+10D^2+9)x = D^2e^{-t} + 3e^{-t} - \sin(2t)D$
$= e^{-t} + 3e^{-t} - 2\cos(2t)$

$(D^4+10D^2+9)x = 4e^{-t} - 2\cos(2t)$
$M = D^2$
$(m^2+10m+9) = 0$
$m^2 + 9m + m + 9 = 0$
$m = -1, -9$
$D^2 = -1 \quad ; \quad D^2 = -9$
$D = \pm i \quad ; \quad D = \pm 3i$

$CF = [(c_1 + c_2x)\cos x + (c_3 + c_4x)\sin 3x]$

$PI = \frac{1}{(D^4+10D^2+9)}[4e^{-t} - 2\cos(2t)]$

$= \frac{4e^{-t}}{D^4+10D^2+9} - \frac{2}{D^4+10D^2+9}\cos 2t$

$D = -1 \quad ; \quad D^2 = -4$

$$= \frac{4e^{-t}}{1+10+9} - \frac{2}{(-4)^2-10\cdot4+9} \cos(2t)$$

$$= \frac{e^{-t}}{5} - \frac{2}{15}\cos(2t)$$

$y = CF + PI$

$$y = [(c_1+c_2x)\cos x + (c_3+c_4x)\sin 3x]\left[\frac{e^{-t}}{5} - \frac{2}{15}\cos 2t\right] + c$$

<u>Q3)</u> $$\frac{d^2y}{dx^2} - y = \frac{2}{1+e^x}$$

<u>Sol:)</u> $(D^2-1)=0$

$D = \pm 1$

$CF = Ae^x + Be^{-x}$

$u = e^x$ ; $v = e^{-x}$

$u' = e^x$ ; $v' = -e^{-x}$

$uv' - u'v = e^x\cdot(-e^{-x}) - e^x e^{-x}$

$= -1 - 1$

$= -2$

$$R = \frac{2}{1+e^x}$$

$$A = -\int \frac{RV}{uv'-u'v}\,dx = +\int \frac{\cancel{2}e^{-x}}{(1+e^x)(\cancel{2})}\,dx$$

$$A = \int \frac{dx}{e^x + e^{2x}}$$

$$= -\frac{1}{e^{x}} - \log|e^{x}| + \log|1+e^{x}| + c_1$$

$$B = \int \frac{R U_1 dx}{-2} \Rightarrow \int \frac{x e^{x}}{1+e^{x}(-x)} dx$$

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

$$= -\log|1+e^{x}| + c_2$$

$$y = \left[-\frac{1}{e^{x}} - \log|e^{x}| + \log|1+e^{x}| + c_1\right]e^{x} - [\log|1+e^{x}| + c_2]e^{-x}$$

Q5) $x^2 y'' + x y' - y = x^2 e^{x}$

$$y'' + \frac{y'}{x} - \frac{y}{x^2} = e^{x}$$

$$\left(D^2 + \frac{D}{x} - \frac{1}{x^2}\right)y = e^{x}$$

$R = e^{x}$

$x^2 y'' + x y' - y = 0$

$[D(D-1) + D - 1]y = 0$

$D^2 - 1 = 0$

$D = \pm 1$

$y = Ae^{z} + Be^{-z}$

$\Rightarrow z = \log x$

$y = Ae^{\log x} + Be^{-\log x}$

$= Ax + \frac{B}{x}$

$u = x, \quad v = \frac{1}{x}$

$u' = 1 \quad ; v' = -\frac{1}{x^2}$

$uv' - u'v = x \cdot \frac{1}{x^2} - 1 \times \frac{1}{x} \Rightarrow -\frac{2}{x}$

$A = -\int \frac{Rudx}{\frac{2}{x}} \Rightarrow -\int \frac{e^x \cdot \frac{1}{x}}{\frac{2}{x}} dx$

$\Rightarrow \frac{1}{2} e^x + c_1$

$B = \int \frac{RU}{\frac{-2}{x}} dx \Rightarrow \int \frac{e^x x}{\frac{-2}{x}} \Rightarrow -\frac{1}{2} \int x^2 e^x dx$

$\Rightarrow -\frac{1}{2} [x^2 e^x - 2xe^x + 2e^x] + C_2$

$y = \{\frac{1}{2} e^x \cdot x + c_1\} - \frac{1}{2} [x^2 e^x - 2xe^x + 2e^x + C_2] \frac{1}{x}$

Q6)

$W = \begin{vmatrix} y_1 & y_2 \\ y_1' & y_2' \end{vmatrix} \Rightarrow \begin{vmatrix} e^x & e^{-x} \\ e^x & -e^{-x} \end{vmatrix}$

$= -e^{-x} \cdot e^x - e^x \cdot e^{-x}$

$\Rightarrow -2 \neq 0$

So, clearly it is linearly independent

Newton's

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Q7) $x^4 + 3x^3 - x^2 + 5x = 2$

Sol:) $P_0(x) = 1 \Rightarrow AI = A \cdot P_0(x)$ {where A is const.}

$P_1(x) = x$

$P_2(x) = \frac{1}{2}[3x^2 - 1]$

$2P_2 = 3x^2 - 1$

$x^2 = \frac{2}{3}P_2(x) + \frac{1}{3}P_0(x)$

$P_3(x) = \frac{1}{2}[5x^3 - 3x]$

$5x^3 = 2P_3(x) + 3x$

$x^3 = \frac{2}{5}P_3(x) + \frac{3}{5} \cdot P_1(x)$

$P_4(x) = \frac{1}{8}(35x^4 - 30x^2 + 3)$

$35x^4 = 8P_4(x) + 30x^2 - 3$

$35x^4 = 8P_4(x) + 30[\frac{2}{3}P_2(x) + \frac{1}{3}P_0(x)] - 3P_0(x)$

$= \frac{1}{35}[8P_4(x) + 20P_2(x) + 10P_0(x) + 3P_0(x)]$

$x^4 = \frac{1}{35}[8P_4(x) + 20P_2(x) + 7P_0(x)]$

\# $x^4 + 3x^3 - x^2 + 5x - 2 = 0$

$\frac{1}{35}[8P_4(x) + 20P_2(x) + 7P_0(x)] + 3[\frac{2}{5}P_3(x) + \frac{3}{5}P_1(x)] -$

$\frac{2}{3}P_2(x) + \frac{1}{3}P_0(x) + 5P_1(x) - 2P_0(x) - \cancel{\times 0}$

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$P_3(x) = \frac{1}{2}[5x^3 - 3x]$

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$x^3 = \frac{2}{5} P_3(x) + \frac{3}{5} \cdot P_1(x)$

$P_4(x) = \frac{1}{8}(35x^4 - 30x^2 + 3)$

$35x^4 = 8P_4(x) + 30x^2 - 3$

$35x^4 = 8P_4(x) + 30\left[\frac{2}{3} P_2(x) + \frac{1}{3} P_0(x)\right] - 3P_0(x)$

$= \frac{1}{35}[8P_4(x) + 20P_2(x) + 10P_0(x) + 3P_0(x)]$

$x^4 = \frac{1}{35}[8P_4(x) + 20P_2(x) + 7P_0(x)]$

\# $x^4 + 3x^3 - x^2 + 5x - 2 = 0$

$\frac{1}{35}[8P_4(x) + 20P_2(x) + 7P_0(x)] + 3\left[\frac{2}{5} P_3(x) + \frac{3}{5} P_1(x)\right] -$

$\frac{2}{3} P_2(x) + \frac{1}{3} P_0(x) + 5P_1(x) - 2P_0(x) \rightarrow 0$

Q9) $\frac{d}{dx}[x J_n J_{n+1}] = x[J_n^2 - J_{n+1}^2]$

Sol:) $J_n J_{n+1} + x[J'_n J_{n+1} + J_n J'_{n+1}]$ — ①

from 3rd recurrence relation

$J'_n = J_{n-1} - \frac{n}{x} J_n$

Replace by n+1

$J'_{n+1} = J_n - \frac{n+1}{x}(J_{n+1})$ — ②

from 4th recurrence relation

$J'_n = -J_{n+1} + \frac{n}{x} J_n$ — ③

On substituting

$J_n J_{n+1} - x J_{n+1}^2 + n J_n J_{n+1} + x J_n^2 - (n+1) J_n J_{n+1}$
$= x(J_n^2 + J_{n+1}^2) \longrightarrow$ HP

Q10) $x\frac{d^2y}{dx^2} + \frac{dy}{dx} + xy = 0$

Sol:) $P_0(x) = x$ ; $P_1(x) = 1$ ; $P_2(x) = x$

Now at $x = 0$ ; $P_0(0) = 0 \rightarrow$ singular point

| | |
|---|---|
| $\lim\limits_{x\to a} (x-a)\frac{P_1(x)}{P_0(x)}$ | $\lim\limits_{x\to a} (x-a)^2\frac{P_2(x)}{P_0(x)}$ |
| $\lim\limits_{x\to 0} x \cdot \frac{1}{x}$ | $\lim\limits_{x\to 0} x^2 \cdot \frac{x}{x} = 0$ finite |

By frobenious method

$$y = \sum_{n=0}^{\infty} a_n x^{m+n}$$

$$\frac{dy}{dx} = \sum_{n=0}^{\infty} (m+n) a_n x^{m+n-1}$$

$$\frac{d^2y}{dx^2} = \sum_{n=0}^{\infty} (m+n)(m+n-1) a_n x^{m+n-2}$$

Put the value of $y, \frac{dy}{dx}$ & $\frac{d^2y}{dx^2}$ in eq ①

$$\Rightarrow x\left[\sum_{n=0}^{\infty}(m+n)(m+n-1)a_n x^{m+n-2}\right] + \left[\sum_{n=0}^{\infty}(m+n)a_n x^{m+n-1}\right] + x\left[\sum_{n=0}^{\infty} a_n x^{m+n}\right]$$

$$\Rightarrow \sum_{n=0}^{\infty}(m+n)(m+n-1)a_n x^{m+n-1} + \sum_{n=0}^{\infty} a_n x^{m+n+1}$$

$$\Rightarrow \sum_{n=0}^{\infty}\left[(m+n)(m+n-1)+(m+n)\right]a_n x^{m+n-1} + \sum_{n=0}^{\infty} a_n x^{m+n+1} = 0$$

$$\Rightarrow \sum_{n=0}^{\infty}\left[(m+n)^2 a_n x^{m+n-1}\right] + \sum_{n=0}^{\infty} a_n x^{m+n+1} = 0 \quad -②$$

now equating least power of $x$ i.e $x^{m-1} = 0$

$$(m^2)a_0 = 0$$

$$m^2 = 0 \Rightarrow m = 0, 0$$

$$m_1 = 0,\ m_2 = 0$$

from eq ②

$$\sum_{n=0}^{\infty}(m+n+1)^2 a_{n+1} x^{m+n} + \sum_{n=0}^{\infty} a_{n-1} x^{m+n} = 0$$

$$\sum_{n=0}^{\infty}\{(m+n+1)^2 a_{n+1} + a_{n-1}\}x^{m+n} = 0 \quad -③$$

Put the coeff of $x^{m+1} = 0$

$$(m+n+1)^2 a_{n+1} + a_{n-1} = 0$$

$$a_{n+1} = \frac{-1}{(m+n+1)^2} a_{n-1}$$

Put $n = 1$

$$a_2 = -\frac{1}{(m+2)^2} a_0$$

$n = 2$

$$a_3 = -\frac{1}{(m+3)^2} a_1 \quad [a_1 = 0]$$

Now by equating coeff of $x^m$ both side

$$(m+1)^2 a_1 x^m = 0$$

$$a_1 = 0$$

$a_3 = 0$ ; put $n = 3$

$$a_4 = \frac{-1}{(m+4)^2} a_3 \quad [a_3 = 0]$$

$$a_4 = 0$$

$n = 4$

$$a_5 = \frac{-1}{(m+5)^2} a_4 \ ; \ a_5 = 0$$

Now

$$\Rightarrow \sum_{n=0}^{\infty} a_n x^{m+n}$$

$$= a_0 x^m + a_1 x^{m+1} + a_2 x^{m+2} + a_3 x^{m+3} + a_4 x^{m+4} + \cdots$$

$$\Rightarrow x^m [a_0 + 0(n) - \frac{x^2}{(m+2)^2} + (0)x^3 + (0)x^4 + \cdots \infty]$$

$$\Rightarrow y = x^m [a_0 - \frac{a_0 x^2}{(m+2)^2}]$$

$$y = a_0 x^m \left[1 - \frac{x^2}{(m+2)^2}\right] \quad -⑤$$

$$y = C_1 (y)_{m=0} + C_2 \left(\frac{dy}{dm}\right)_{m=0}$$

$$(y)_{m=0} = a_0 x^0 \left[1 - \frac{x^2}{2^2}\right]$$

$$\Rightarrow a_0 \left[1 - \frac{x^2}{2^2}\right]$$

Now partially diff. eq ⑤ wrt m

$$\frac{dy}{dm} = a_0 x^m \log x \left[1 - \frac{x^2}{(m+2)^2}\right] + a_0 x^m \left[0 - \left(\frac{-2x^2}{(m+2)^3}\right)\right]$$

$$= a_0 x^m \log x \left[1 - \frac{x^2}{(m+2)^2}\right] + a_0 x^m \left[\frac{2x^2}{(m+2)^3}\right]$$

$$\left.\frac{dy}{dm}\right)_{m=0} \Rightarrow a_0 (1) \log x \left[1 - \frac{x^2}{2^2}\right] + a_0 (1) \left[\frac{2x^2}{2^3}\right]$$

$$y = C_1 \left[a_0 \left(1 - \frac{x^2}{2^2}\right)\right] + C_3 \left\{a_0 \left[\log \left(1 - \frac{x^2}{2^2}\right) + \frac{2x^2}{2^3}\right]\right.$$

$$y = A\left(1 - \frac{x^2}{2^2}\right) + B\left[\log x \left(1 - \frac{x^2}{2^2}\right) + \frac{2x^2}{2^3}\right. \rightarrow \text{Ans}$$

**Q4)** $2x(1-x)\frac{d^2y}{dx^2} + (1-x)\frac{dy}{dx}$

Sol:) $P_0(x) = 2x(1-x)$

$P_1(x) = 1-x$

$P_2(x) = 3$

now at $x = 0$

~~$P(0)$~~ $P_0(0) = 0 \longrightarrow$ singular pt

$P_1(0) = 1$

$P_2(0) = 3$

(1) Determination of

$$\lim_{x \to a} (x-a) \frac{P_1(x)}{P_0(x)} \qquad \lim_{x \to a} (x-a)^2 \frac{P_2(x)}{P_0(x)}$$

$$\lim_{x \to 0} \frac{x(1-x)}{2x(1-x)} = \frac{1}{2} \qquad \lim_{x \to 0} (x-0)^2 \frac{3}{2x(1-x)}$$

$$\lim_{x \to 0} \frac{x^{\cancel{2}} 3}{2x(1-x)}$$

$$\lim_{x \to 0} \to 0 \text{ (finite)}$$

Now it is regular singular point

By Frobenious method :-

$$y = \sum_{n=0}^{\infty} a_n x^{m+n}$$

$$\frac{dy}{dx} = \sum_{n=0}^{\infty} (m+n) a_n x^{m+n-1}$$

$$\frac{d^2y}{dx^2} = \sum_{n=0}^{\infty} (m+n)(m+n-1) a_n x^{m+n-2}$$

Now, put the value of $y, \frac{dy}{dx}, \frac{d^2y}{dx^2}$

$$\Rightarrow 2x(1-x)\left[\sum_{n=0}^{\infty} (m+n)(m+n-1) a_n x^{m+n-2}\right] + (1-n)\left[\sum_{n=0}^{\infty} (m+n) a_n x^{m+n-1}\right]$$
$$+ 3\left[\sum_{n=0}^{\infty} a_n x^{m+n}\right] = 0$$

$$\Rightarrow 2x - 2n^2\left[\sum (m+n)(m+n-1) a_n x^{m+n-2}\right] + (1-n)\left[\sum_{n=0}^{\infty} (m+n) a_n x^{m+n-1}\right]$$
$$+ 3\left[\sum_{n=0}^{\infty} a_n x^{m+n}\right] = 0$$

$$\Rightarrow \sum_{n=0}^{\infty} 2(m+n)(m+n-1) a_n x^{m+n-1} - \sum_{n=0}^{\infty} 2(m+n)(m+n-1) a_n x^{m+n} + \sum_{n=0}^{\infty} (m+n) a_n x^{m+n-1}$$
$$- \sum_{n=0}^{\infty} (m+n) a_n x^{m+n} + \sum_{n=0}^{\infty} 3 a_n x^{m+n} = 0$$

$$\Rightarrow \sum_{n=0}^{\infty}[2(m+n)(m+n-1)+m+n]a_n x^{m+n-1} - \sum_{n=0}^{\infty}[2(m+n)(m+n-1)+(m+n)-3]a_n x^{m+n}$$

$$\Rightarrow \sum_{n=0}^{\infty}[2(m+n-1)+1](m+n)a_n x^{m+n-1} - \sum_{n=0}^{\infty}[[2(m+n-1)+1](m+n)-3]a_n x^{m+n}=0$$

$$\Rightarrow \sum_{n=0}^{\infty}(2m+2n-1)(m+n)a_n x^{m+n-1} - \sum_{n=0}^{\infty}[(2m+2n-1)(m+n)-3]a_n x^{m+n}=0$$

$$\Rightarrow \sum_{n=0}^{\infty}(2m+2n-1)(m+n)a_n x^{m+n-1} - \sum_{n=0}^{\infty}(2(m+n)^2-(m+n)^{-3}]a_n x^{m+n}=0$$

$$\Rightarrow \sum_{n=0}^{\infty}(2m+2n-1)(m+n)a_n x^{m+n-1} - \sum_{n=0}^{\infty}(2(m+n)^2-(m+n)-3]a_n x^{m+n}=0$$

$$\Rightarrow \sum_{n=0}^{\infty}(2m+2n-1)(m+n)a_n x^{m+n-1} - \sum_{n=0}^{\infty}[2(m+n)-3)(m+n-1)]a_n x^{m+n}=0 \quad -②$$

Now, put co-eff of lowest power of $x$ i.e:- $x^{m-1}$ to zero

$$(2m+2n-1)(m+n)a_n=0$$
$$(2m+0-1)(m+0)a_0=0$$
$$(2m-1)(m)a_0=0$$
$$(2m-1)(m)=0$$
$$m=\frac{1}{2}\ ;\ m=0$$

Now $m_1 \neq m_2$

$m_1-m_2=\frac{1}{2}$ ; $\frac{1}{2} \neq$ integer.

from eq ②

$$\Rightarrow \sum_{n=0}^{\infty}[2m+2(n+1)-1](m+n-1)a_{n+1}x^{m+n} - \sum_{n=0}^{\infty}(2m+2n-3)(m+n+1)a_n x^{m+n}=0$$

$$\Rightarrow \sum_{n=0}^{\infty}(2m+2n+1)(m+n+1)a_{n+1}x^{m+n} - (2m+2n-3)(m+n-1)a_n]x^{m+n}$$

Now by equating co-eff. of $x^{m+n}$ to zero

$D_n = 4n\lambda R$

$(2m+2n+1)(m+n+1)a_{n+1} = (2m+2n-3)(m+n+1)a_n = 0$

$$a_{n+1} = \frac{(2m+2n-3)\cancel{(m+n-1)}\,a_n}{(2m+2n+1)\cancel{(m+n-1)}}$$

put $n=0$ in eq ③

$$a_1 = \left(\frac{2m-3}{2m+1}\right)a_0$$

put $n=1$ in eq ③

$$a_2 = \left(\frac{2m-1}{2m+3}\right)a_1 \Rightarrow \frac{2m-1}{2m+3} \times \left(\frac{2m-3}{2m+1}\right)a_0$$

$$a_2 = \frac{(2m-1)(2m-3)}{(2m+3)(2m+1)}a_0$$

Put $n=2$ in eq 3

$$a_3 = \left(\frac{2m+1}{2m+5}\right)a_2$$

$$\Rightarrow \left(\frac{\cancel{2m+1}}{2m+5}\right)\left[\frac{(2m-1)(2m-3)}{(2m+3)\cancel{(2m+1)}}\right]a_0$$

$$\Rightarrow \frac{(2m-1)(2m-3)}{(2m+5)(2m+3)}a_0$$

$$y = C_1(y)_{m=m_1} + C_2(y)_{m=m_2} \quad \text{— ④}$$

$$y = \sum_{n=0}^{\infty} a_n x^{m+n} = a_0x^m + a_1x^{m+1} + a_2x^{m+2} + a_3x^{m+3} + \text{----}$$

Put the value of $a_0, a_1, a_2, a_3$ we get

$$y = a_0x^m + \left[\left(\frac{2m-3}{2m+1}\right)a_0\right]x^{m+1} + \left\{\frac{(2m-1)(2m-3)}{(2m+3)(2m-1)}a_0\right]x^{m+2} +$$

$$\left[\frac{(2m-1)(2m-3)}{(2m+5)(2m+3)}a_0\right]x^{m+3} \text{---}$$

termination of wavelength of Na light using Newton's Ring

$D_n^2 = 4n\lambda R$ —— (1) Diameter for dark ring

$(y)_{m=\frac{1}{2}} = a_0\sqrt{x} + \frac{(1-3)}{(1+1)} a_0 x^{3/2} + \left[\frac{(1-1)(1-3)}{(1+3)(1+1)} a_0\right] x^{5/2} + \left[\frac{(1-1)(1-3)}{(1+5)(1+3)} a_0 x^{7/2}\right]$

$\Rightarrow a_0\sqrt{x} + \frac{(-2)}{2} a_0 x^{3/2} + 0 + 0 - - -$

$\Rightarrow a_0 (x^{1/2} - x^{3/2})$

Now, at $m=0$

$(y)_{m=0} = a_0 x^0 + \frac{(-3)}{(-1)} a_0 x^1 + \frac{(-1)(-3)}{(3)(1)} a_0 x^2 + \frac{(-1)(-3)}{(5)(3)} a_0 x^3 + - - -$

$(y)_{m=0} = a_0 [1 - 3x + x^2 + \frac{1}{5}x^3 + - - - + \infty]$

Now eq (4)

$y = c_1 (y)_{m=\frac{1}{2}} + c_2 (y)_{m=0}$

$= c_1 [a_0 (x^{1/2} - x^{3/2})] + c_2 [a_0 (1 - 3x + x^2 + \frac{x^3}{5} + - - - \infty)]$

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