Exercise 3.3

Q.1 $\int \frac{-2x}{\sqrt{4-x^2}}\,dx$

$= \int (4-x^2)^{-1/2}\,(-2x)\,dx$

$= \frac{(4-x^2)^{-1/2+1}}{-1/2+1} + c$

$= 2(4-x^2)^{1/2} + c$ Ans.

Q.2 $\int \frac{dx}{x^2+4x+13}$

$= \int \frac{dx}{x^2+4x+4+9}$ Put $x+2=z$, $dx = dz$

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

$\int \frac{dz}{z^2+3^2}$

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$= \frac{1}{3}\tan^{-1}\left(\frac{z}{3}\right) + c$ By back substitution

$= \frac{1}{3}\tan^{-1}\left(\frac{x+2}{3}\right) + c$ Ans.

Q.3 $\int x\sqrt{x+a}\,dx$

Put $\sqrt{x+a} = z$, $x+a = z^2$, $x = z^2 - a$, $dx = 2z\,dz$

$= \int (z^2-a)\,z\;2z\,dz$

$= 2\int (z^2-a)z^2\,dz$

$= 2\int z^4\,dz - 2\int z^2 a\,dz$

$= 2\frac{z^5}{5} - 2a\frac{z^3}{3} + c$

$= \frac{2}{5}z^5 - \frac{2a}{3}z^3 + c$ By back substitutions.

$= \frac{2}{5}(\sqrt{x+a})^5 - \frac{2a}{3}(\sqrt{x+a})^3 + c$ Ans.

Q.4 $\int \frac{x^2}{4+x^2}\,dx$

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

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

$= \int dx - 4\int \frac{dx}{x^2+(2)^2}$

$= x - 4\cdot\frac{1}{2}\tan^{-1}\left(\frac{x}{2}\right) + c$

$= x - 2\tan^{-1}(x/2) + c$ Ans.

Q.5 $\int \frac{1}{x\ln x}\,dx$

let $\ln x = z$, $\frac{1}{x}dx = dz$

$\int \frac{1}{\ln x}\cdot\left(\frac{1}{x}dx\right)$

$\int \frac{1}{z}\,dz$

$= \ln|z| + c$ Putting $z = \ln x$ back

$= \ln|\ln x| + c$ Ans

Q.6 $\int \frac{e^x}{e^x+3}\,dx$ Let $e^x+3 = z$, $e^x dx = dz$

$= \int \frac{dz}{z}$

$= \ln z + c$

Putting $e^x+3 = z$ back

$= \ln|e^x+3| + c$ Ans.

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* $\sqrt{x^2-a^2}$ Putting $x = a\sec\theta$ or $x = a\csc\theta$
* $\sqrt{a^2-x^2}$ put $x = a\cos\theta$ or $x = a\sin\theta$
* $\sqrt{a^2+x^2}$ put $x = a\tan\theta$ or $x = a\cot\theta$

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Q.7 $\displaystyle\int \frac{(x+b)\,dx}{(x^2+2bx+c)^{1/2}}$

$$=\frac{1}{2}\int (x^2+2bx+c)^{-1/2}\cdot(2x+2b)\,dx$$

$$=\frac{1}{2}\left[\frac{(x^2+2bx+c)^{-1/2+1}}{-1/2+1}\right]+c$$

$$=\frac{1}{2}\left[2\,(x^2+2bx+c)\right]+c$$

$$=\sqrt{x^2+2bx+c}+c \quad \text{Ans.}$$

Q.8 $\displaystyle\int \frac{\sec^2 x}{\sqrt{\tan x}}\,dx$ Let

$\tan x = z$

$\sec^2 x\,dx = dz$

$$=\int \frac{dz}{\sqrt{z}}$$

$$=\int z^{-1/2}\,dz$$

$$=\frac{z^{-1/2+1}}{-1/2+1}+c$$

$$=2z^{1/2}+c \Rightarrow 2\sqrt{z}+c$$

Put $z=\tan x$ back

$$=2\sqrt{\tan x}+c \quad \text{Ans.}$$

Q.9 $\displaystyle\int \frac{3x(2x^2+1)\,dx}{x^4+x^2+1}$

$$=\int \frac{6x^3+3x}{x^4+x^2+1}\,dx$$

$$=\frac{3}{2}\int \frac{4x^3+2x}{x^4+x^2+1}\,dx \qquad \because \int \frac{f'(x)}{f(x)}=\ln|f(x)|$$

$$=\frac{3}{2}\cdot \ln|x^4+x^2+1|+c$$

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

Q.10 (a) Show that $\displaystyle\int \frac{dx}{\sqrt{x^2-a^2}}=\ln\left(x+\sqrt{x^2-a^2}\right)+c$

$$LHS=\int \frac{dx}{\sqrt{x^2-a^2}}$$

Let $x=a\sec\theta \Rightarrow dx=a\sec\theta\tan\theta\,d\theta$

$$=\int \frac{a\sec\theta\tan\theta\,d\theta}{\sqrt{a^2\sec^2\theta-a^2}} \Rightarrow \int \frac{a\sec\theta\tan\theta\,d\theta}{\sqrt{a^2(\sec^2\theta-1)}}$$

$$=\int \frac{a\sec\theta\tan\theta\,d\theta}{a\sqrt{\tan^2\theta}} \Rightarrow \int \frac{\cancel{a}\sec\theta\cancel{\tan\theta}\,d\theta}{\cancel{a}\cancel{\tan\theta}}$$

$$=\int \sec\theta\,d\theta$$

$$=\ln|\sec\theta+\tan\theta|+c_1$$

$\sec\theta=\frac{x}{a} \Rightarrow \tan\theta=\sqrt{\sec^2\theta-1}$

$\tan\theta=\frac{\sqrt{x^2-a^2}}{a}$

$$=\ln\left|\frac{x}{a}+\frac{\sqrt{x^2-a^2}}{a}\right|+c_1$$

$$=\ln\left|\frac{x+\sqrt{x^2-a^2}}{a}\right|+c_1$$

$$=\ln\left(x+\sqrt{x^2-a^2}\right)+(c_1-\ln a)$$

where $c_1-\ln a=c$ (any Constant)

$$=\ln\left(x+\sqrt{x^2-a^2}\right)+c$$

Thus $\displaystyle\int \frac{dx}{\sqrt{x^2-a^2}}=\ln\left(x+\sqrt{x^2-a^2}\right)+c$ (Proved)

(b) $\displaystyle\int \sqrt{a^2-x^2}\,dx$

Let $x=a\sin\theta \Rightarrow dx=a\cos\theta\,d\theta$

$$=\int \sqrt{a^2-a^2\sin^2\theta}\;.\;a\cos\theta\,d\theta$$

$$=\int \sqrt{a^2(1-\sin^2\theta)}\;a\cos\theta\,d\theta$$

$$=\int a^2\sqrt{\cos^2\theta}\,\cos\theta\,d\theta$$

$$=a^2\int \cos^2\theta\,d\theta$$

$$=a^2\int \frac{1+\cos 2\theta}{2}\,d\theta$$

$\because \cos 2\theta = 2\cos^2\theta - 1$

$\cos^2\theta = \frac{1+\cos 2\theta}{2}$

$$= \frac{a^2}{2}\int d\theta + \frac{a^2}{2}\int \cos 2\theta \, d\theta$$

$$= \frac{a^2}{2}\theta + \frac{a^2}{2}\cdot\frac{\sin 2\theta}{2} + c$$

$$= \frac{a^2}{2}\theta + \frac{a^2}{4}\cdot 2\sin\theta\cos\theta + c$$

$$= \frac{a^2}{2}\theta + \frac{a^2}{2}\sin\theta\cos\theta + c$$

Now $x = a\sin\theta \Rightarrow \sin\theta = x/a$

$\theta = \sin^{-1}(x/a)$

$\cos\theta = \sqrt{1-\sin^2\theta} = \sqrt{1-\frac{x^2}{a^2}}$

$\cos\theta = \frac{\sqrt{a^2-x^2}}{a}$

$$= \frac{a^2}{2}\sin^{-1}(x/a) + \frac{a^2}{2}\cdot\frac{x}{a}\cdot\frac{\sqrt{a^2-x^2}}{a} + c$$

$$= \frac{a^2}{2}\sin^{-1}(x/a) + \frac{x}{2}\sqrt{a^2-x^2} + c$$

(Proved)

Q.11 $\int \frac{dx}{(1+x^2)^{3/2}}$ let $x = \tan\theta$

$dx = \sec^2\theta \, d\theta$

$$= \int \frac{\sec^2\theta \, d\theta}{(1+\tan^2\theta)^{3/2}}$$

$$= \int \frac{\sec^2\theta \, d\theta}{(\sec^2\theta)^{3/2}} \quad \because 1+\tan^2\theta = \sec^2\theta$$

$$= \int \frac{\sec^2\theta}{\sec^3\theta} d\theta \Rightarrow \int \frac{1}{\sec\theta} d\theta$$

$$= \int \cos\theta \, d\theta$$

$$= \sin\theta + c$$

$$= \frac{x}{\sqrt{x^2+1}} + c$$

Ans.

Now

$\cot\theta = 1/x$

$\sqrt{1+\cot^2\theta} = \csc\theta$

$\frac{\sqrt{x^2+1}}{x} = \csc\theta$

$\sin\theta = \frac{x}{\sqrt{x^2+1}}$

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Q.12 $\int \frac{1}{(1+x^2)\tan^{-1}x} dx$ let

$\tan^{-1}x = z$

$$= \int \frac{1}{\tan^{-1}x}\cdot\left(\frac{1}{1+x^2}dx\right) \qquad \frac{1}{1+x^2}dx = dz$$

$$\int \frac{dz}{z}$$

$$= \ln|z| + c \qquad \text{Putting } z = \tan^{-1}z \text{ back.}$$

$$= \ln|\tan^{-1}x| + c$$

Q.13 $\int \sqrt{\frac{1+x}{1-x}} dx$

$$= \int \sqrt{\frac{1+x}{1-x}} \times \frac{\sqrt{1+x}}{\sqrt{1+x}} dx$$

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

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

$$= \int \frac{1}{\sqrt{1-x^2}} dx - \frac{1}{2}\int (1-x^2)^{-1/2}(-2x)dx$$

$$= \sin^{-1}x - \frac{1}{2}\cdot\frac{(1-x^2)^{-1/2+1}}{-1/2+1} + c$$

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

$$= \sin^{-1}x - \sqrt{1-x^2} + c \quad \text{Ans.}$$

Q.14 $\int \frac{\sin\theta}{1+\cos^2\theta} d\theta$ let

$\cos\theta = z$

$-\sin\theta \, d\theta = dz$

$\sin\theta \, d\theta = -dz$

$$\int \frac{-dz}{1+z^2}$$

$$= \cot^{-1}(z) + c \qquad \text{putting } z = \cos\theta \text{ back.}$$

$$= \cot^{-1}(\cos\theta) + c \quad \text{Ans}$$

$$\left(\because \int \frac{-dx}{1+x^2} = \cot^{-1}x + c\right)$$

Q.15 $\int \frac{ax}{\sqrt{a^2-x^4}}dx$ let $x^2=z$

$2x\,dx=dz$

$\int \frac{a\,dz}{2\sqrt{a^2-z^2}}$ $x\,dx=\frac{dz}{2}$

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$=\frac{a}{2}\int\frac{dz}{\sqrt{a^2-z^2}}$

$=\frac{a}{2}\sin^{-1}\left(\frac{z}{a}\right)+c$

Putting $z=x^2$ back.

$=\frac{a}{2}\sin^{-1}\left(\frac{x^2}{a}\right)+c$ Ans.

Q.16 $\int\frac{dx}{\sqrt{7-6x-x^2}}$

$=\int\frac{dx}{\sqrt{7+9-9-6x-x^2}}$

$=\int\frac{dx}{\sqrt{16-(x^2+6x+9)}} \Rightarrow \int\frac{dx}{\sqrt{(4)^2-(x+3)^2}}$

$=\sin^{-1}\left(\frac{x+3}{4}\right)+c$ Ans.

Q.17 $\int\frac{\cos x}{\sin x\ \ln|\sin x|}dx$

let $\ln|\sin x|=z$

$=\int\frac{1}{\ln|\sin x|}\cdot\left(\frac{\cos x}{\sin x}dx\right)$ $\frac{1}{\sin x}\cdot\cos x\,dx=dz$

$=\int\frac{1}{z}dz$ $\frac{\cos x}{\sin x}dx=dz$

$=\ln|z|+c$

Putting $z=\ln|\sin x|$ back.

$=\ln|\ln\sin x|+c$ Ans.

Q.18 $\int\cos x\left(\frac{\ln\sin x}{\sin x}\right)dx$

$=\int\left(\frac{\cos x}{\sin x}\right)dx\cdot\ln\sin x$ let $z=\ln\sin x$

$dz=\frac{\cos x}{\sin x}dx$

$=\int z\,dz \Rightarrow \frac{z^2}{2}+c$

$\frac{1}{2}(\ln|\sin x|)^2+c$ Ans.

Q.19 $\int\frac{x\,dx}{4+2x+x^2}$

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

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

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

$=\frac{1}{2}\int\frac{2x+2}{x^2+2x+4}-\int\frac{dx}{x^2+2x+1+3}$

$=\frac{1}{2}\ln|x^2+2x+4|-\int\frac{dx}{(x+1)^2+(\sqrt{3})^2}$

$=\frac{1}{2}\ln|x^2+2x+4|-\frac{1}{\sqrt{3}}\tan^{-1}\left(\frac{x+1}{\sqrt{3}}\right)+c$ Ans.

Q.20 $\int\frac{x}{x^4+2x^2+5}dx$

$=\int\frac{dz/2}{z^2+2z+5}$ Let $x^2=z$

$2x\,dx=dz$

$x\,dx=\frac{dz}{2}$

$=\frac{1}{2}\int\frac{dz}{z^2+2z+1+4}$

$=\frac{1}{2}\int\frac{dz}{(z+1)^2+(2)^2}$

$=\frac{1}{2}\cdot\frac{1}{2}\tan^{-1}\left(\frac{z+1}{2}\right)+c$

$=\frac{1}{4}\tan^{-1}\left(\frac{z+1}{2}\right)+c$

Putting $z=x^2$ back, we have

$=\frac{1}{4}\tan^{-1}\left(\frac{x^2+1}{2}\right)+c$ Ans.

Q.21 $\int\sin^5x\ dx$

$=\int\sin^4x\cdot\sin x\,dx$

$=\int(\sin^2x)^2\sin x\,dx$

$\int(1-\cos^2x)^2\cdot\sin x\,dx$

$\int(1+\cos^4x-2\cos^2x)\sin x\,dx$

$= \int \sin x\,dx + \int \cos^4 x \sin x\,dx - 2\int \cos^2 x \sin x\,dx$

$= \int \sin x\,dx - \int \cos^4 x(-\sin x)\,dx + 2\int \cos^2 x(-\sin x)\,dx$

$= -\cos x - \frac{\cos^5 x}{5} + \frac{2}{3}\cos^3 x + c$

$= -\cos x - \frac{1}{5}\cos^5 x + \frac{2}{3}\cos^3 x + c$ Ans.

Q.22 $\int \cos^7 x\,dx$

$= \int \cos^6 x \cos x\,dx \Rightarrow \int (\cos^2 x)^3 \cdot \cos x\,dx$

$= \int (1-\sin^2 x)^3 \cos x\,dx$

$= \int (1 - \sin^6 x - 3\sin^2 x + 3\sin^4 x)\cos x\,dx$

$= \int \cos x\,dx - \int \sin^6 x \cos x\,dx - 3\int \sin^2 x \cos x\,dx + 3\int \sin^4 x \cos x\,dx$

$= \sin x - \frac{1}{7}\sin^7 x - \frac{3}{3}\sin^3 x + \frac{3}{5}\sin^5 x + c$

$= \sin x - \frac{1}{7}\sin^7 x - \sin^3 x + \frac{3}{5}\sin^5 x + c$ Ans.

Q.23 $\int \cos\left(\sqrt{x} - \frac{x}{2}\right)\cdot\left(\frac{1}{\sqrt{x}} - 1\right)dx$

let $\sqrt{x} - \frac{x}{2} = z$

$\left(\frac{1}{2\sqrt{x}} - \frac{1}{2}\right)dx = dz$

$\cancel{2}\times\frac{1}{\cancel{2}}\left(\frac{1}{\sqrt{x}} - 1\right)dx = 2dz$

$\left(\frac{1}{\sqrt{x}} - 1\right)dx = 2dz$

$\int 2\cos z\,dz \Rightarrow 2\sin z + c$

$= 2\sin\left(\sqrt{x} - \frac{x}{2}\right) + c$ Ans.

Q.24 $\int \frac{x+2}{\sqrt{x+3}}\,dx$ let $\sqrt{x+3} = z$

$x+3 = z^2$

$x = z^2 - 3$

$dx = 2z\,dz$

$= \int \frac{(z^2-3+2)}{z}\,2z\,dz$

$\int (z^2-1)2\,dz$

$= 2\int z^2\,dz - 2\int dz$

$= 2\frac{z^3}{3} - 2z + c$

Putting $z = \sqrt{x+3}$ back

$= \frac{2}{3}\left(\sqrt{x+3}\right)^3 - 2\sqrt{x+3} + c$ Ans.

Q.25 $\int \frac{\sqrt{2}}{\sin x + \cos x}\,dx$

$= \int \frac{\sqrt{2}\,dx}{\left(\frac{1}{\sqrt{2}}\sin x + \frac{1}{\sqrt{2}}\cos x\right)\sqrt{2}}$ Multipl. and dividing by $\sqrt{2}$. Den.

$= \int \frac{dx}{\cos x \frac{1}{\sqrt{2}} + \sin x \frac{1}{\sqrt{2}}}$

$\because \sin\frac{\pi}{4} = \cos\frac{\pi}{4} = \frac{1}{\sqrt{2}}$

$= \int \frac{dx}{\cos x \cos\frac{\pi}{4} + \sin x \sin\frac{\pi}{4}}$ $\left(\because \cos(\alpha-\beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta\right)$

$= \int \frac{dx}{\cos(x-\pi/4)} \Rightarrow \int \sec(x-\pi/4)\,dx$

$= \ln\left|\sec(x-\pi/4) + \tan(x-\pi/4)\right| + c$ Ans.

Q.26 $\int \frac{dx}{\cos x \frac{\sqrt{3}}{2} + \sin x \cdot \frac{1}{2}}$

$\because \cos\frac{\pi}{6} = \frac{\sqrt{3}}{2}$ & $\sin\frac{\pi}{6} = \frac{1}{2}$

$= \int \frac{dx}{\cos x \cos\frac{\pi}{6} + \sin x \sin\frac{\pi}{6}}$

$= \int \frac{dx}{\cos(x-\pi/6)} \Rightarrow \int \sec(x-\pi/6)\,dx$

$= \ln\left|\sec(x-\pi/6) + \tan(x-\pi/6)\right| + c$ Ans.

Q.27 $\int x^3\sqrt{1+x^2}\,dx$

let $x = \tan\theta$

$dx = \sec^2\theta\, d\theta$

$= \int \tan^3\theta \cdot \sqrt{1+\tan^2\theta}\,\sec^2\theta\, d\theta$

$= \int \tan^3\theta \cdot \sqrt{\sec^2\theta}\,\sec^2\theta\, d\theta$

$= \int \tan^3\theta \cdot \sec\theta\,\sec^2\theta\, d\theta$

$= \int \tan^3\theta\,\sec^3\theta\, d\theta$

$= \int \tan^2\theta\,\sec^2\theta \cdot (\tan\theta\sec\theta)\,d\theta$

$= \int (\sec^2\theta - 1)\sec^2\theta\,(\tan\theta\sec\theta)\,d\theta$

$= \int (\sec^4\theta - \sec^2\theta)\tan\theta\sec\theta\, d\theta$

$= \int \sec^4\theta\cdot(\tan\theta\sec\theta)\,d\theta - \int \sec^2\theta(\sec\theta\tan\theta)\,d\theta$

$= \frac{1}{5}\sec^5\theta - \frac{1}{3}\sec^3\theta + c$

Now $x = \tan\theta \Rightarrow \sec\theta = \sqrt{1+\tan^2\theta}$

$\sec\theta = \sqrt{1+x^2}$

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

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

Q.28 $\int x\sqrt{1+x}\,dx$ let $\sqrt{1+x} = z$

$1+x = z^2$

$x = z^2 - 1$

$dx = 2z\,dz$

$\int (z^2-1)z\cdot(2z\,dz)$

$= \int (z^2-1)2z^2\,dz$

$= \int (2z^4 - 2z^2)\,dz$

$= 2\int z^4\,dz - 2\int z^2\,dz$

$= \frac{2}{5}z^5 - \frac{2}{3}z^3 + c$ Putting $z = \sqrt{1+x}$ back.

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

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

Q.29 $\int \frac{dx}{(1+x)^{3/2}(1-x)^{1/2}}$

Let $x = \cos\theta$

$dx = -\sin\theta\,d\theta$

$= \int \frac{-\sin\theta\,d\theta}{(1+\cos\theta)^{3/2}(1-\cos\theta)^{1/2}}$

$= \int \frac{-\sin\theta\,d\theta}{(2\cos^2\frac{\theta}{2})^{3/2}\cdot(2\sin^2\frac{\theta}{2})^{1/2}}$

$= \int \frac{-\sin\theta\,d\theta}{2^{3/2}\cos^3\frac{\theta}{2}\cdot 2^{1/2}\sin\frac{\theta}{2}}$

$= \frac{1}{2^{4/2}}\int \frac{-2\sin\frac{\theta}{2}\cos\frac{\theta}{2}\,d\theta}{\cos^3\frac{\theta}{2}\cdot\sin\frac{\theta}{2}}$

$= \frac{-2}{4}\int \frac{d\theta}{\cos^2\frac{\theta}{2}}$

$= \frac{-2}{4}\int \sec^2\frac{\theta}{2}\,d\theta$

$= \frac{-1}{2}\,\frac{\tan\frac{\theta}{2}}{1/2} + c$

$= -\frac{2}{2}\tan\frac{\theta}{2} + c$

$= -\tan\frac{\theta}{2} + c$

$\because \cos\theta = 1 - 2\sin^2\frac{\theta}{2} = 2\cos^2\frac{\theta}{2} - 1$

$\because \cos\theta = 2\cos^2\frac{\theta}{2} - 1$

$x = \cos\theta$

$\Rightarrow x+1 = 2\cos^2\frac{\theta}{2}$

$\cos^2\frac{\theta}{2} = \frac{x+1}{2} \Rightarrow \sec^2\frac{\theta}{2} = \frac{2}{x+1}$

$\sqrt{\sec^2\frac{\theta}{2} - 1} = \tan\frac{\theta}{2}$

$\sqrt{\left(\frac{2}{x+1}\right) - 1} = \tan\frac{\theta}{2}$

$\tan\frac{\theta}{2} = \sqrt{\frac{2-x-1}{x+1}} = \sqrt{\frac{1-x}{1+x}}$

$\Rightarrow -\sqrt{\frac{1-x}{1+x}} + c$ Ans.