Theorem 3.4. *Assume that x be unit speed spacelike curve in $\mathbf{Q}^2$ with the moving asymptotic orthonormal frame $\{x, \alpha, y\}$ and cone curvature κ and let γ_{xy} be $xy-$smarandache curve with asymptotic orthonormal frame $\{\gamma_{xy}, \alpha_{xy}, y_{xy}\}$. Then the following relations hold:*

i) *The asymptotic orthonormal frame $\{\gamma_{xy}, \alpha_{xy}, y_{xy}\}$ of the $xy-$smarandache curve γ_{xy} is given as*

$$\begin{bmatrix} \gamma_{xy} \\ \alpha_{xy} \\ y_{xy} \end{bmatrix} = \begin{bmatrix} \sqrt{\frac{c}{2b}} & 0 & \sqrt{\frac{b}{2c}} \\ 0 & 1 & 0 \\ \frac{b\kappa^2\sqrt{2bc}}{(c-b\kappa)^2} & 0 & \frac{c\sqrt{2bc}}{(c-b\kappa)^2} \end{bmatrix} \begin{bmatrix} x \\ \alpha \\ y \end{bmatrix}. \tag{3.15}$$

ii) *The cone curvature $\kappa_{\gamma_{xy}}(s^*)$ of the curve γ_{xy} is given by*

$$\kappa_{\gamma_{xy}}(s^*) = \frac{2bc\kappa(s)}{(c - b\kappa(s))^2}, \tag{3.16}$$

where

$$s^* = \frac{1}{\sqrt{2cb}} \int (c - b\kappa(s))\, ds. \tag{3.17}$$

Proof. **i)** We assume that the curve x is a unit speed spacelike curve with the asymptotic orthonormal frame $\{x, \alpha, y\}$ and cone curvature κ. Differentiating the equation (3.14) with respect to s and taking into account (2.1), we have

$$\gamma'_{xy}(s^*)\frac{ds^*}{ds} = \frac{1}{\sqrt{2cb}}(c - b\kappa(s))\,\overrightarrow{\alpha}(s). \tag{3.18}$$

By considering (3.17), we get

$$\gamma'_{xy}(s^*) = \alpha(s) = \alpha_{xy}. \tag{3.19}$$

Here, it can be readily observed that the tangent vector $\overrightarrow{\alpha}_{xy}$ is a unit spacelike vector.

$$\gamma''_{xy}(s^*)\frac{ds^*}{ds} = \kappa x(s) - y(s). \tag{3.20}$$

By substituting (3.17) into (3.20) and making necessary calculations, we obtain

$$\gamma''_{xy}(s^*) = \frac{\kappa\sqrt{2bc}}{(c - b\kappa)}\overrightarrow{x} - \frac{\sqrt{2bc}}{(c - b\kappa)^2}\overrightarrow{y}. \tag{3.21}$$

By the help of equation $y_{xy}(s^*) = -\gamma''_{xy} - \frac{1}{2}\left\langle \gamma''_{xy}, \gamma''_{xy} \right\rangle \gamma_{xy}$, we write

$$y_{xy}(s^*) = \frac{b\sqrt{2bc}.\kappa^2}{(c - b\kappa)^2}x(s) + \frac{c\sqrt{2bc}}{(c - b\kappa)^2}y(s). \tag{3.22}$$

ii) The curvature $\kappa_{\gamma_{xy}}(s^*)$ of the $\gamma_{xy}(s^*)$ is explicity obtained by

$$\kappa_{\gamma_{xy}}(s^*) = \frac{-\left\langle \gamma''_{xy}, \gamma''_{xy} \right\rangle}{2} = \frac{2bc\kappa(s)}{(c - b\kappa(s))^2}.$$

□

Definition 3.5. *Assume that x be unit speed spacelike curve lying on $\mathbf{Q}^2$ with the moving asymptotic orthonormal frame $\{x, \alpha, y\}$. At that time, $\alpha y-$smarandache curve of x is defined by*

$$\gamma_{\alpha y}(s^*) = \alpha(s) + \frac{b}{c} y(s), \tag{3.23}$$

where $c, b \in \mathbb{R}_0^+$.

Theorem 3.6. *Assume that x be unit speed spacelike curve in $\mathbf{Q}^2$ with the moving asymptotic orthonormal frame $\{x, \alpha, y\}$ and cone curvature κ and let $\gamma_{\alpha y}$ be $\alpha y-$smarandache curve with asymptotic orthonormal frame $\{\gamma_{\alpha y}, \alpha_{\alpha y}, y_{\alpha y}\}$. At the time the following relations hold:*

i) *The asymptotic orthonormal frame $\{\gamma_{\alpha y}, \alpha_{\alpha y}, y_{\alpha y}\}$ of the $\alpha y-$smarandache curve $\gamma_{\alpha y}$ is given as*

$$\begin{bmatrix} \gamma_{\alpha y} \\ \alpha_{\alpha y} \\ y_{\alpha y} \end{bmatrix} = \begin{bmatrix} 0 & 1 & \frac{b}{c} \\ \frac{c\sqrt{\kappa}}{\sqrt{b^2-2c^2}} & \frac{b\sqrt{\kappa}}{\sqrt{b^2-2c^2}} & \frac{c\sqrt{\kappa}}{\kappa\sqrt{b^2-2c^2}} \\ \omega_1 & \omega_2 & \omega_3 \end{bmatrix} \begin{bmatrix} x \\ \alpha \\ y \end{bmatrix}, \tag{3.24}$$

where

$$\begin{aligned} \zeta_1 &= \frac{c\kappa'}{b^2 - 2c^2} \left(\frac{c - 2\kappa b}{2\kappa} \right), \\ \zeta_2 &= \frac{c\kappa'}{b^2 - 2c^2} \left(\frac{c - b - 1}{2\kappa} \right), \\ \zeta_3 &= \frac{c\kappa'}{b^2 - 2c^2} \left(\frac{b\kappa - c}{2\kappa^2} \right) \end{aligned} \tag{3.25}$$

and

$$\begin{aligned} \omega_1 &= -\zeta_1, \\ \omega_2 &= -(\zeta_2 + \frac{1}{2}\left(2\zeta_1\zeta_3 + \zeta_2^2\right)), \\ \omega_3 &= -(\zeta_3 + \frac{b}{2c}\left(2\zeta_1\zeta_3 + \zeta_2^2\right)). \end{aligned} \tag{3.26}$$

ii) *The cone curvature $\kappa_{\gamma_{\alpha y}}(s^*)$ of the curve $\gamma_{\alpha y}$ is given by*

$$\kappa_{\gamma_{\alpha y}}(s^*) = \frac{-c^2}{8\left(b^2 - 2c^2\right)^2} (\frac{\kappa'}{\kappa})^2 \left(\frac{(c - 2\kappa b)(b\kappa - c)}{\kappa} + (c - b - 1)^2 \right), \tag{3.27}$$

where

$$s^* = \frac{\sqrt{b^2 - 2c^2}}{c} \int \sqrt{\kappa(s)} ds. \tag{3.28}$$

Proof. **i)** Let the curve x be a unit speed spacelike curve with the asymptotic orthonormal frame $\{x, \alpha, y\}$ and cone curvature κ. Differentiating the equation (3.23) with respect to s and taking into account (2.1), we find

$$\gamma'_{\alpha y}(s^*) \frac{ds^*}{ds} = \kappa \overrightarrow{x(s)} - \frac{b}{c} \kappa \overrightarrow{\alpha(s)} - \overrightarrow{y(s)}.$$

This can be written as following

$$\alpha_{\alpha y}(s^*)\frac{ds^*}{ds} = \kappa\overrightarrow{x(s)} - \frac{b}{c}\kappa\overrightarrow{\alpha(s)} - \overrightarrow{y(s)}, \tag{3.29}$$

where

$$\frac{ds^*}{ds} = \frac{\sqrt{b^2-2c^2}}{c}\sqrt{\kappa(s)}. \tag{3.30}$$

By substituting (3.30) into (3.29), we find

$$\alpha_{\alpha y}(s^*) = \frac{c\sqrt{\kappa}}{\sqrt{b^2-2c^2}}\overrightarrow{x} - \frac{b\sqrt{\kappa}}{\sqrt{b^2-2c^2}}\overrightarrow{\alpha} - \frac{c\sqrt{\kappa}}{\kappa\sqrt{b^2-2c^2}}\overrightarrow{y}. \tag{3.31}$$

Differentiating (3.31) and using (3.30), we get

$$\gamma''_{\alpha y}(s^*) = \zeta_1 x(s) + \zeta_2\alpha(s) + \zeta_3 y(s),$$

where $\zeta_1 = \frac{c\kappa'}{b^2-2c^2}\left(\frac{c-2\kappa b}{2\kappa}\right), \zeta_2 = \frac{c\kappa'}{b^2-2c^2}\left(\frac{c-b-1}{2\kappa}\right), \zeta_3 = \frac{c\kappa'}{b^2-2c^2}\left(\frac{b\kappa-c}{2\kappa^2}\right).$

$$y_{\alpha y}(s^*) = -\gamma''_{\alpha y} - \frac{1}{2}\left\langle\gamma''_{\alpha y}, \gamma''_{\alpha y}\right\rangle\gamma_{\alpha y}. \tag{3.32}$$

By the help of equation (3.32), we obtain

$$y_{\alpha y}(s^*) = \omega_1 x(s) + \omega_2\alpha(s) + \omega_3 y(s), \tag{3.33}$$

where $\omega_1 = -\zeta_1, \omega_2 = -(\zeta_2 + \frac{1}{2}\left(2\zeta_1\zeta_3 + \zeta_2^2\right)), \omega_3 = -(\zeta_3 + \frac{b}{2c}\left(2\zeta_1\zeta_3 + \zeta_2^2\right)).$

ii) The curvature $\kappa_{\gamma_{\alpha y}}(s^*)$ of the $\gamma_{\alpha y}(s^*)$ is explicity obtained by

$$\kappa_{\gamma_{\alpha y}}(s^*) = -\frac{c^2}{8\left(b^2-2c^2\right)^2}\left(\frac{\kappa'}{\kappa}\right)^2\left(\frac{(c-2\kappa b)(b\kappa-c)}{\kappa} + (c-b-1)^2\right).$$

□

Definition 3.7. *Assume that x be unit speed spacelike curve lying on $\mathbf{Q}^2$ with the moving asymptotic orthonormal frame $\{x,\alpha,y\}$. Then, $x\alpha y-$smarandache curve of x is defined by*

$$\gamma_{x\alpha y}(s^*) = \frac{1}{\sqrt{2cc^*+b^2}}\left(cx(s) + b\alpha(s) + c^*y(s)\right), \tag{3.34}$$

where $c, c^*, b \in \mathbb{R}_0^+$.

Theorem 3.8. *Assume that x be unit speed spacelike curve in $\mathbf{Q}^2$ with the moving asymptotic orthonormal frame $\{x,\alpha,y\}$ and cone curvature κ and let $\gamma_{x\alpha y}$ be $x\alpha y-$smarandache curve with asymptotic orthonormal frame $\{\gamma_{x\alpha y}, \alpha_{x\alpha y}, y_{x\alpha y}\}$. Then the following relations hold:*

i) *The asymptotic orthonormal frame $\{\gamma_{x\alpha y}, \alpha_{x\alpha y}, y_{x\alpha y}\}$ of the $x\alpha y-$smarandache curve $\gamma_{x\alpha y}$ is given as*

$$\begin{bmatrix}\gamma_{x\alpha y}\\ \alpha_{x\alpha y}\\ y_{x\alpha y}\end{bmatrix} = \begin{bmatrix}\frac{c}{\sqrt{2cc^*+b^2}} & \frac{b}{\sqrt{2cc^*+b^2}} & \frac{c^*}{\sqrt{2cc^*+b^2}}\\ \rho_1 & \rho_2 & \rho_3\\ \sigma_1 & \sigma_2 & \sigma_3\end{bmatrix}\begin{bmatrix}x\\ \alpha\\ y\end{bmatrix} \tag{3.35}$$

where

$$\eta = \sqrt{\left(c - c^{*}\kappa(s)\right)^{2} - 2b^{2}\kappa(s)};$$
$$\rho_1 = \frac{b\kappa(s)}{\eta}, \rho_2 = \frac{c - c^{*}\kappa(s)}{\eta}, \rho_3 = -\frac{b}{\eta}; \tag{3.36}$$
$$\xi_1 = \left(\rho_1' + \rho_2\kappa\right), \xi_2 = \rho_2' + \rho_1 + \rho_3\kappa, \xi_3 = -\rho_3' - \rho_2$$

and

$$\sigma_1 = -\xi_1 - \frac{c}{2\sqrt{2cc^{*} + b^{2}}}\left(2\xi_1\xi_3 + \xi_2^{2}\right),$$
$$\sigma_2 = -\xi_2 - \frac{b}{2\sqrt{2cc^{*} + b^{2}}}\left(2\xi_1\xi_3 + \xi_2^{2}\right), \tag{3.37}$$
$$\sigma_3 = -\xi_3 - \frac{c^{*}}{2\sqrt{2cc^{*} + b^{2}}}\left(2\xi_1\xi_3 + \xi_2^{2}\right).$$

ii) *The cone curvature $\kappa_{\gamma_{x\alpha y}}(s^{*})$ of the curve $\gamma_{x\alpha y}$ is given by*

$$\kappa_{\gamma_{yx\alpha}}(s^{*}) = \left(b\left(\frac{\kappa}{\eta}\right)' + \frac{c - c^{*}\kappa}{\eta}\kappa\right)\left(\left(\frac{b}{\eta}\right)' + \frac{c - c^{*}\kappa}{\eta}\right)$$
$$- \frac{1}{2}\left(\frac{c - c^{*}\kappa}{\eta}\right)', \tag{3.38}$$

where

$$s^{*} = \frac{1}{\sqrt{2cc^{*} + b^{2}}}\int \sqrt{\left(c - c^{*}\kappa(s)\right)^{2} - 2b^{2}\kappa(s)}ds,\ b, c, c^{*} \in \mathbb{R}_0^{+}. \tag{3.39}$$

Proof. **i)** Differentiating the equation (3.34) with respect to s and taking into account (2.1), we find

$$\gamma_{x\alpha y}'(s^{*})\frac{ds^{*}}{ds} = \frac{1}{\sqrt{2cc^{*} + b^{2}}}\left(b\kappa\overrightarrow{x(s)} + \left(c - c^{*}\kappa\right)\overrightarrow{\alpha(s)} - \overrightarrow{by(s)}\right). \tag{3.40}$$

This can be written as follows

$$\alpha_{x\alpha y}(s^{*}) = \frac{b\kappa}{\eta}\overrightarrow{x(s)} + \frac{c - c^{*}\kappa}{\eta}\overrightarrow{\alpha(s)} - \frac{b}{\eta}\overrightarrow{y(s)} \tag{3.41}$$

or

$$\alpha_{x\alpha y}(s^{*}) = \rho_1\overrightarrow{x(s)} + \rho_2\overrightarrow{\alpha(s)} - \rho_3\overrightarrow{y(s)}, \tag{3.42}$$

where

$$\frac{ds^{*}}{ds} = \frac{1}{\sqrt{2cc^{*} + b^{2}}}\sqrt{\left(c - c^{*}\kappa\right)^{2} - 2b^{2}\kappa}. \tag{3.43}$$

Differentiating (3.42) and using (3.43), we get

$$\gamma_{xy\alpha}''(s^{*}) = \xi_1 x(s) + \xi_2\alpha(s) + \xi_3 y(s),$$

where $\xi_1 = \left(\rho_1' + \rho_2\kappa\right), \xi_2 = \rho_2' + \rho_1 + \rho_3\kappa, \xi_3 = -\rho_3' - \rho_2$.

$$y_{x\alpha y}(s^{*}) = -\gamma_{x\alpha y}'' - \frac{1}{2}\left\langle\gamma_{x\alpha y}'', \gamma_{x\alpha y}''\right\rangle\gamma_{x\alpha y}. \tag{3.44}$$

By the help of equation (3.44), we obtain

$$y_{xay}(s^*) = \sigma_1 x(s) + \sigma_2\alpha(s) + \sigma_3 y(s), \tag{3.45}$$

where $\sigma_1 = -\xi_1 - \frac{c}{2\sqrt{2cc^*+b^2}}\left(2\xi_1\xi_3+\xi_2^2\right)$, $\sigma_2 = -\xi_2 - \frac{b}{2\sqrt{2cc^*+b^2}}\left(2\xi_1\xi_3+\xi_2^2\right)$, $\sigma_3 = -\xi_3 - \frac{c^*}{2\sqrt{2cc^*+b^2}}\left(2\xi_1\xi_3+\xi_2^2\right)$.

ii) From $\kappa_{\gamma_{x\alpha y}}(s^*) = -\frac{1}{2}\left\langle \gamma''_{x\alpha y}, \gamma''_{x\alpha y}\right\rangle$, we have

$$\kappa_{\gamma_{yx\alpha}}(s^*) = \left(b\left(\frac{\kappa}{\eta}\right)' + \frac{c-c^*\kappa}{\eta}\kappa\right)\left(\left(\frac{b}{\eta}\right)' + \frac{c-c^*\kappa}{\eta}\right) - \frac{1}{2}\left(\frac{c-c^*\kappa}{\eta}\right)'.$$

□

Theorem 3.9. *Let $x : I \to \mathbf{Q}^2 \subset E_1^3$ be a spacelike curve in $\mathbf{Q}^2$ as follows*

$$x(s) = \frac{f_s^{-1}}{2}(f^2-1, 2f, f^2+1), \tag{3.46}$$

for some non constant function $f(s)$. Then we can write the following conditions:

***1)** If x is a $x\alpha-$smarandache curve, then the $x\alpha-$smarandache curve $\gamma_{x\alpha}$ can be written as*

$$\gamma_{x\alpha}(s^*) = (\frac{c}{b} - f_s^{-1}f_{ss})x(s) + (f,1,f). \tag{3.47}$$

***2)** If x is a $xy-$smarandache curve, then the $xy-$smarandache curve γ_{xy} can be written as*

$$\gamma_{xy}(s^*) = \frac{1}{\sqrt{2bc}}\begin{pmatrix} (c-\frac{1}{2}f_s^{-2}f_{ss}^2)x(s) + f_s^{-1}f_{ss}(f,1,f) \\ -f_s(1.0,1)\end{pmatrix}. \tag{3.48}$$

***3)** If x is a $\alpha y-$smarandache curve, then the $\alpha y-$smarandache curve $\gamma_{\alpha y}$ can be written as*

$$\gamma_{\alpha y}(s^*) = \begin{pmatrix} \left(-f_s^{-1}f_{ss} - \frac{b}{2c}f_s^{-2}f_{ss}^2\right)x(s) + \left(1+\frac{b}{c}f_s^{-1}f_{ss}\right)(f,1,f) \\ -\frac{b}{c}f_s(1.0,1)\end{pmatrix}. \tag{3.49}$$

***4)** If x is a $x\alpha y-$smarandache curve, then the $x\alpha y-$smarandache curve $\gamma_{x\alpha y}$ can be written as*

$$\gamma_{x\alpha y}(s^*) = \frac{1}{\sqrt{2cc^*+b^2}}\begin{pmatrix} \left(c - bf_s^{-1}f_{ss} - \frac{c^*}{2}f_s^{-2}f_{ss}^2\right)x(s) \\ +\left(b+c^*f_s^{-1}f_{ss}\right)(f,1,f) - f_s(1.0,1)\end{pmatrix}, \tag{3.50}$$

where $c, b, c^* \in \mathbb{R}_0^+$.

Proof. It is obvious from (3.1), (3.14), (3.23), (3.34) and (3.46). □

We can give the following example to hold special Smarandache curves in the null cone $\mathbf{Q}^2$. Special $x\alpha$, xy, αy, and $x\alpha y-$smarandache curves of x curves are given in Figure 1 A, C, E, G, I, respectively. These figures rotated in three dimensions are also given in Figure 1 B, D, F, H, J, respectively.

Example 3.10. *The curve*

$$x(s) = \left(\frac{\cosh s}{2} - \frac{1}{\cosh s}, \tanh s, \frac{\cosh s}{2}\right)$$

is spacelike in $\mathbf{Q}^2$ with arc length parameter s. Also, the shape of the x curve is given as follows:

Then we can write the smarandache curves of the x curve as follows:

i) *$x\alpha-$smarandache curve $\gamma_{x\alpha}$ is given by*

$$\gamma_{x\alpha}(s)=\begin{pmatrix} d\left(\frac{\cosh s}{2}-\frac{1}{\cosh s}\right)+\frac{\sinh s}{2}-\frac{\tanh s}{\cosh s}, \\ d\tanh s+\frac{1}{\cosh^2 s}, \\ d\frac{\cosh s}{2}+\frac{\sinh s}{2} \end{pmatrix}$$

ii) *$xy-$smarandache curve γ_{xy} is given by*

$$\gamma_{xy}(s)=\begin{pmatrix} m\cosh s-n\tanh s\sinh s-d\left(\frac{1c+\tanh^2 s}{\cosh s}\right), \\ c\tanh s\left(e-\frac{\tanh^2 s}{2}\right), \\ d\left(\left(c-\frac{\tanh^2 s}{2}\right)\frac{\cosh s}{2}-\frac{1}{\cosh s}\right) \end{pmatrix}$$

iii) *$\alpha y-$ smarandache curve $\gamma_{\alpha y}$ is given by*

$$\gamma_{\alpha y}(s)=\begin{pmatrix} \begin{pmatrix} \left(\frac{\cosh s}{2}-\frac{1}{\cosh s}\right)(1-e\tanh s)\tanh s \\ +\sinh s\,(1+d\tanh s)-d\cosh s \end{pmatrix}, \\ -\tanh^2 s\,(1+d\tanh s)+d\tanh s, \\ \frac{\sinh s}{2}-d\cosh s-e\sinh s\tanh s \end{pmatrix}$$

iv) *$x\alpha y-$smarandache curve $\gamma_{x\alpha y}$ is given by*

$$\gamma_{x\alpha y}(s)=\begin{pmatrix} \begin{pmatrix} m\sinh s-n\cosh s+d\sinh s\tanh s \\ -\frac{c}{\cosh s}-\frac{b\sinh s-c^*\tanh^2 s}{\cosh^2 s} \end{pmatrix}, \\ m+n\tanh s+k\tanh^2 s+l\tanh^3 s, \\ m\cosh s+d\sinh s+c\tanh s\sinh s, \end{pmatrix}$$

where $m,n,d,c,k,l,e\in\mathbb{R}_0^+$.

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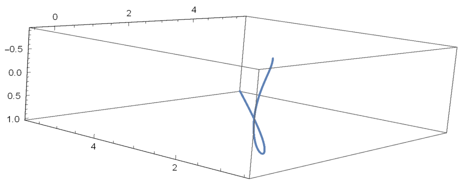
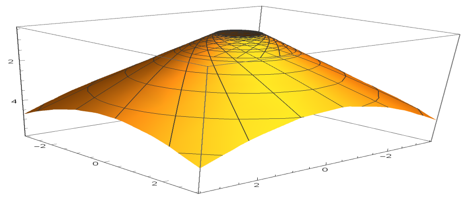
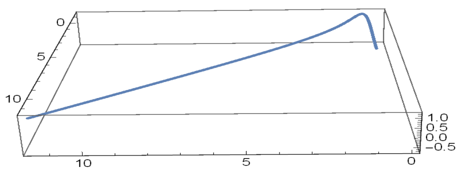


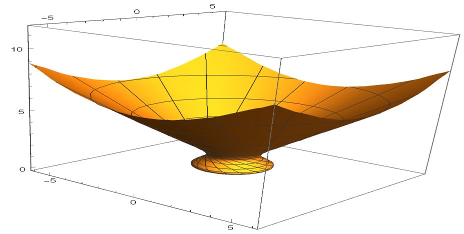
(A) The curve x



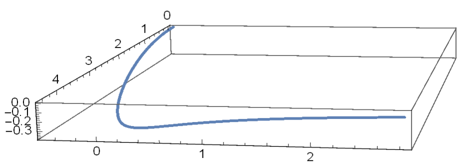
(B) The rotated surface of curve x



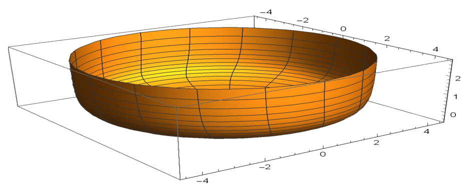
(C) $x\alpha-$smarandache curve



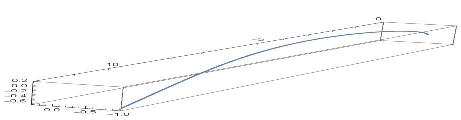
(D) $x\alpha$- smarandache surface.



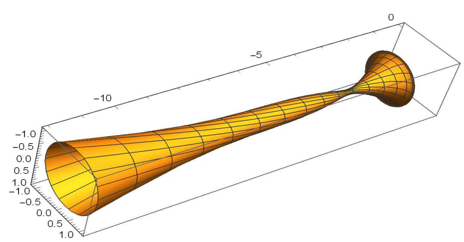
(E) $xy-$smarandache curve



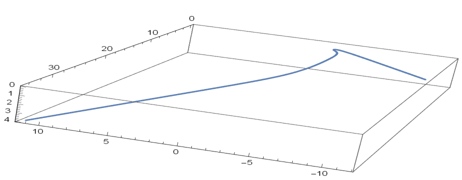
(F) $xy-$smarandache surface.



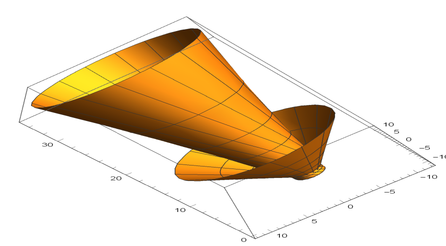
(G) αy$-$smarandache curve.



(H) αy$-$smarandache surface.



(I) $x\alpha$y$-$smarandache curve.



(J) $x\alpha$y$-$smarandache surface.

FIGURE 1. Graphics of smarandache surfaces and smarandache curves

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