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IMPLEMENTATION OF CURVED SHAPES IN TEXTILE DESIGN

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Abstract: *The constantly growing demands of consumers, the creation of new materials, require designers to react quickly and offer the most modern items. When creating modern products, it is necessary to take into account aspects of different cultures in design. The solution to this problem is the use of curved shapes. This type of shapes have been used since ancient times to the present day, in the creation of items of clothing. Adapted, researched and used in the work is a software tool for complex, express, automated production of geometric elements with an oval shape, in a combination of current color trends, as well as for their application in modern textile design. The results of this study can be applied in the training of future specialists in the study of shapes and design of clothing.*

Keywords: *Textile pattern, fashion design, motif, parametric equation, butterfly curve, rose curve, Lissajous figure*

1. INTRODUCTION

The modern development of information and communication technologies offer more and more opportunities for designers to offer their products and services worldwide [1],[2]. On the other hand, the constantly growing demands of consumers, the creation of new materials expect designers to react quickly and offer the most modern items.

One of the main problems is the creation of designs that meet the demands of consumers who are of different nationalities [3]. This problem remains relevant at the present stage of development of science and technology [4].

It is necessary to take into account aspects of different cultures in design. The solution to this problem is the use of curved shapes. This type of forms have been used since ancient times to the present day, in the creation of elements of clothing, in architecture, interior design, in the manufacture of household items [5], [6]. These forms are typical of many cultures around the world. Curved shapes are characterized by the fact that they can be used to obtain beautiful elements for textile design, using simple algorithms [7].

A similar problem is observed in the perception of colors by consumers. An important point is that the shape and color of the elements of which they are composed are interrelated [8]. When designing new patterns and clothes, the designer must take into account the color preferences of consumers from different cultures. In most cases, color is the first sign that the consumer of textiles and clothing makes his choice whether to prefer or reject a product [9], [10].

In this paper, algorithms for obtaining curved shapes are reviewed, after which, they are used to generate aesthetically pleasing shapes for textile design.

2. ALGORITHMS FOR GENERATING CURVED SHAPES

The beauty and balance of natural forms have their mathematical descriptions. Such forms can be found in plants, shells, insects. Natural forms often have symmetry, similarity, periodicity.

This section offers descriptions and pseudocode algorithms for obtaining a total of five curves of shapes borrowed from nature. These forms implemented as *.m files in the Matlab software system (The MathWorks Inc.) and as spreadsheets in MS Excel (Microsoft Corp.). they are presented in Appendices A, B, C and D.

2.1. Rose curve

The rose curve, represented as pseudocode algorithm on figure 1, resembles the shape of the flower of the same name. It was proposed by the Italian mathematician Guido Grandi between 1723 and 1728 because it resembled a rose [11]. If n is odd, the rose has n-leaves. If n is even, then the rose has 2n leaves. If n is a rational number, then the curve closes at an angle in the polar coordinate system π.s.p, where p=1 if n is odd and p=2 if n is even. If n is irrational, then the rose has an infinite number of leaves.

$$\theta = 0, \frac{\pi}{64}, 10^2.\pi$$
$$r = \cos(n.\theta)$$
$$x = r.\cos(\theta)$$
$$y = r.\sin(\theta)$$
$$draw(x, y)$$

Fig. 1. *Pseudocode for creating a rose curve*

2.2.Maurer curve

The Maurer curve [12] is defined by the radius r and the angle θ in a polar coordinate system. The variable n is a positive integer. The resulting figure is a "rose" with n-leaves if n is an odd number and 2n-leaves if it is even. The angle d is a positive integer given in degrees. To obtain all 360 points of the figure, then θ=[0, 360]. Figure 2 shows a pseudocode by which a Maurer figure is drawn, by calculating parametric equations, after switching from a polar to a Cartesian coordinate system.

$k_1 = \theta d \frac{\pi}{180}$	$k_2 = \theta \frac{\pi}{180}$
$r_1 = 300.\sin(nk_1)$	$r_2 = 300.\sin(nk_2)$
$x_1 = x_0 - r_1.\cos(k_1)$	$x_2 = x_0 - r_2.\cos(k_2)$
$y_1 = y_0 - r_1.\sin(k_1)$	$y_2 = y_0 - r_2.\sin(k_2)$
$draw(x_1, y_1)$	$draw(x_2, y_2)$
a) internal contour	б) external countour

Fig. 2. *Pseudocode for creating a Maurer curve*

2.3.Butterfly curve

The butterfly curve [13] is defined by the radius r and its angle θ in a polar coordinate system. The upper line represents the axis of the upper right wing, and the end point of the wing is the furthest point from the beginning. In the same way, the middle right wing, the lower right wing, the body and the tail of the butterfly are obtained. Figure 3 shows the pseudocode of a butterfly curve program after switching from a polar to a Cartesian coordinate system.

$$\theta = 0, \frac{\pi}{64}, 10\pi$$
$$r = e^{sin\theta} - 2.\cos(4\theta) - sin^5\left(\frac{2\theta - \pi}{24}\right)$$
$$x = r.\cos(\theta)$$
$$y = r.\sin(\theta)$$
$$draw(x, y)$$

Fig. 3. *Pseudocode for creating a butterfly curve*

2.4. Lissajous figures

Lissajous figures [14] describe the trajectory of a point that performs periodic oscillations in two mutually perpendicular directions. This is a curve described by a point with coordinates x and y, which are periodic functions in time with multiple periods. These figures are used in electronics to compare two periodic signals. For example, if the horizontal deviation x of the oscilloscope is formed by a sinusoidal signal and a vertical deviation – from the cosine signal on the oscilloscope screen a beautiful fixed figure will be formed. A formally expressed Lissajous figure is the diagram corresponding to the parametric equations of the system, realized by pseudocode, in figure 4. The variable k is the radius and changed in the interval [1; b]; b – coefficient expressing the filling of the figure; p.a – frequency of sinusoidal signal; q.a – cosine signal frequency. What Lisaju's figure would look like depends on the p/q ratio. When this ratio is 1, the figure is an ellipse and a circle at p=q.

$$x = k.\sin(pa)$$
$$y = k.\cos(qa)$$
$$draw(x, y)$$

Fig. 4. *Pseudocode to create a Lissajous figure*

2.5.Other figures

This section presents curves obtained by mathematical dependencies. They have a simple shape, but through their combinations and repeats can be obtained attractive textile patterns. The "circle" module is obtained after switching from a polar to a Cartesian coordinate system. The main variables are the angle θ and the radius r. They are used to calculate the points on the circle with coordinates x and y. The astroid module is plotted when raising the third degree transformation equations. For the equilateral triangle and square modules, length l is used. By the corresponding calculations the desired figure is obtained. A pseudocode of algorithms for drawing the proposed modules is presented in Figure 5.

$\theta = 0, 2\pi$ $x = r.\cos(\theta)$ $y = r.\sin(\theta)$ $draw(x, y)$	$\theta = 0, 2\pi$ $x = r.\cos^3(\theta)$ $y = r.\sin^3(\theta)$ $draw(x, y)$
a) circle	*b) asteroid*
$draw\left(x, y, (x + l), y, \left(x + \frac{l}{2}\right), \left(y + \frac{\sqrt{3}}{2} l\right), x, y\right)$	$draw\left(x, y, (x + l), y, (x + l), (y + l), x, (y + l), x, y\right)$
c) equilateral triangle	*d) square*

Fig.5. *Pseudocode of algorithms for obtaining basic figures*

3.CLOTHING MODELS USING ELEMENTS WITH CURVED SHAPES

In the present work, three models of dresses are proposed, using some of the described nonlinear geometric elements. These dresses are shown in Figure 6.

When creating the dress models, a silhouette of the Fit-and-flare type was used. The upper part is tight-fitting and the lower part of the skirt is not. The silhouette is similar to A-shaped or inverted Y-shaped, but has its own specifics, which does not allow it to be assigned to one of the two classic silhouettes. The tight-fitting part is a universal addition to most body types, as it creates a shape with a narrowed waist and a proportionately shaped hip.

The names of the models of dresses are formed, depending on the element used. The colors of Pantone for 2021 are used (https://www.pantone.com). The online tool Design Lab (https://artofwhere.com) was used to visualize the dresses. The models were created in the Inkscape software environment (https://inkscape.org). They consist of a mannequin, a wig and a dress.

a) Model “Rose” b) Model “Butterfly” c) Model “Astroida”

Fig. 6. *Model of dresses*

The "rose" model is composed of a Maurer rose element. The element was obtained at n=2 and d=39. It is lined with orange outlines, placed on a gray background, and the main elements are blue. The repeat is of the half-drop type, without rotation.

In the "butterfly" model, the elements are randomly scattered on the fabric. Each butterfly is two-colored. The color combinations of butterflies are blue-orange, dark red-light red, orange-yellow. Between the individual elements are placed butterflies with a size of 1/3 of the main. They have a blue outline without filling. The butterflies are applied on a neutral background.

The “astroida” model is composed of a combination of the elements of the asteroid and a circle, colored orange and red, respectively. They are placed on a neutral background. The repeat is of the half-drop type. The entire elements are rotated 30 degrees to the vertical axis.

4. DISCUSSION AND CONCLUSION

The results obtained in the present work confirm Wongkaew's thesis [15], that the combination between the body of the mannequin, the shape of the pattern elements and their arrangement on the fabric, materialize the identity of the clothing manufacturer and activate the user's imagination and desire to owns this garment. This turns the fashion into an art form.

In this work, the results of [16] are confirmed. According to the authors, generating shapes with computer-based tools encourages users to compose and experiment with complex and aesthetically pleasing geometric patterns in a much easier way than drawing them by hand.

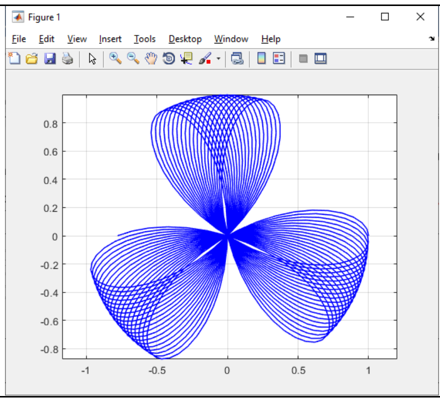
When creating elements of the "rose" type and Lissajous figures, there are infinitely many combinations between the values of the parameters at which these figures are obtained. These parameters are n and d for the "rose" figure, p and q for the Lisaju figures. According to Dunham [17], another challenge is to determine the possible color combinations for the resulting elements.

Adapted, researched and used in the work is a software tool for complex, express, automated production of geometric elements with an oval shape, in a combination of actual colors, as well as for their application in modern textile design.

The results of the research can be applied in the training of future specialists in the study of shapes and design of clothing.

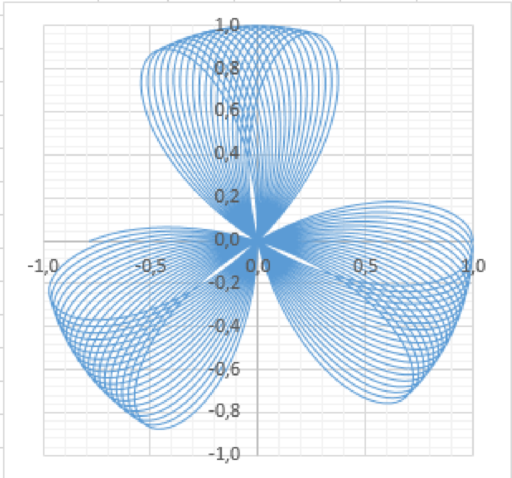
Appendix A. Implementation of a "rose" curve in Matlab program environment and MS Excel

```
tic; clc, clear all, close all
n=4.65; d=1.53; k=n/d
theta=0:pi/64:10*2*pi
r=cos(k*theta)
x=r.*cos(theta)
y=r.*sin(theta)
figure
plot(x,y,'Color','b','linewidth',1)
grid on; axis equal; toc
```



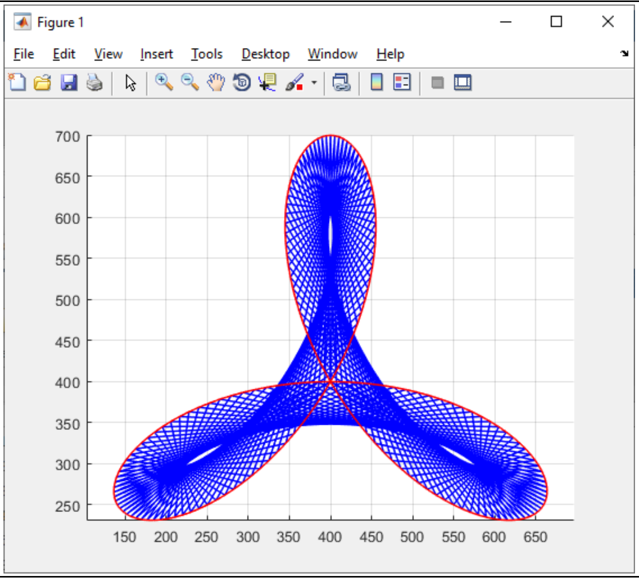
When realizing the "rose" figure in MS Excel, n and d are entered in cells with addresses B2 and C2. In cell E2, enter the formula for k =B2/C2. The angle Theta is calculated by entering a value 0 in cell G2. Enter the formula =G2+PI ()/64 in cell G3. All cells from G3 to G1282 are then filled with this formula. The radius r is calculated by =COS($E$2*G2). The x and y coordinates from which the figure is drawn are calculated by =H2*COS(G2), for x and =H2*SIN(G2), for y.

	A	B	C	D	E	F	G	H	I	J
1		n	d		k		theta	r	x	y
2		4,65	1,53		3,039		0,000	1,000	1,000	0,000
3							0,049	0,989	0,988	0,049
4							0,098	0,956	0,951	0,094
5							0,147	0,902	0,892	0,132
6							0,196	0,827	0,811	0,161
7							0,245	0,734	0,712	0,178
8							0,295	0,625	0,598	0,182
9							0,344	0,502	0,473	0,169
10							0,393	0,368	0,340	0,141
11							0,442	0,226	0,204	0,097
12							0,491	0,079	0,070	0,037
13							0,540	-0,070	-0,060	-0,036
14							0,589	-0,218	-0,181	-0,121
15							0,638	-0,360	-0,289	-0,215
16							0,687	-0,495	-0,383	-0,314
17							0,736	-0,619	-0,458	-0,415
18							0,785	-0,729	-0,515	-0,515



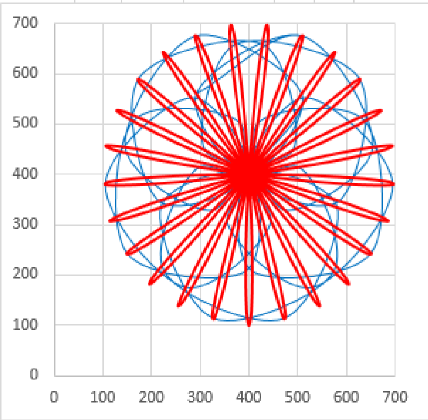
Appendix B. Implementation of Maurer curve in Matlab program environment and MS Excel

```
tic; clc, clear all, close all
n=3; d=29
Xo=400; Yo=400
figure; hold on
theta=0:360
k=theta.*d*pi/180
r=300*sin(n*k)
x1=Xo-r.*cos(k)
y1=Yo-r.*sin(k)
plot(x1,y1,'b','linewidth',1)
theta=0:360
k=theta.*pi/180
r=300*sin(n*k)
x=Xo+r.*cos(k)
y=Yo-r.*sin(k)
plot(x,y,'r','linewidth',1)
grid on; axis equal; toc
```



When realizing the Maurer figure in MS Excel, the value of n is entered in cell B2, and that of d, in cell C2. The beginning of the figure with coordinates A and B are entered in cells E2 and F2. The Theta angle is introduced in the interval [0, 359], with step 1, in cells H2:H361. The formula for k =H2*$C$2*PI()/180, is entered in cell I2 and all cells up to I361 are filled. The nodule d also participates in this formula. The radius of the inner contour r is calculated by =300*SIN($B$2*I2). The X and Y coordinates are calculated by: for X =$E$2-J2*COS(I2), and for Y =$F$2-J2*SIN(I2). When calculating k1, the angle Theta is converted from degrees to radians, by the formula =H2*PI()/180. The radius r1 and the coordinates of the points on the outer contour are calculated similarly to those on the inner contour. For r1 the formula is =300*SIN($B$2*M2), for X it is =$E$2-N2*COS(M2), and for Y =$F$2-N2*SIN(M2).

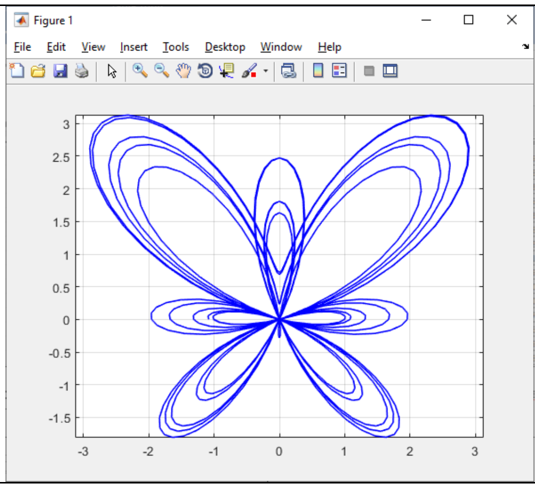
	B	C	D	E	F
1	n	d		A	B
2	25	56		400	400



	H	I	J	K	L	M	N	O	P
1	Theta	k	r	x	y	k1	r1	x1	y1
2	0	0,00	0,00	400,00	400,00	0,00	0,00	400,00	400,00
3	1	0,98	-192,84	507,83	559,87	0,02	126,79	273,23	397,79
4	2	1,95	-295,44	289,33	673,93	0,03	229,81	170,33	391,98
5	3	2,93	-259,81	145,87	454,02	0,05	289,78	110,62	384,83
6	4	3,91	-102,61	326,19	328,72	0,07	295,44	105,28	379,39
7	5	4,89	102,61	382,18	501,05	0,09	245,75	155,19	378,58
8	6	5,86	259,81	162,65	505,67	0,10	150,00	250,82	384,32
9	7	6,84	295,44	149,45	243,44	0,12	26,15	374,05	396,81
10	8	7,82	192,84	393,27	207,28	0,14	-102,61	501,61	414,28
11	9	8,80	0,00	400,00	400,00	0,16	-212,13	609,52	433,18
12	10	9,77	-192,84	218,79	334,05	0,17	-281,91	677,62	448,95
13	11	10,75	-295,44	328,53	113,33	0,19	-298,86	693,37	457,02
14	12	11,73	-259,81	573,85	206,93	0,21	-259,81	654,13	454,02
15	13	12,71	-102,61	501,61	414,28	0,23	-172,07	567,66	438,71
16	14	13,68	102,61	355,02	307,78	0,24	-52,09	450,55	412,60
17	15	14,66	259,81	529,90	175,00	0,26	77,65	325,00	379,90
18	16	15,64	295,44	694,72	379,39	0,28	192,84	214,63	346,85

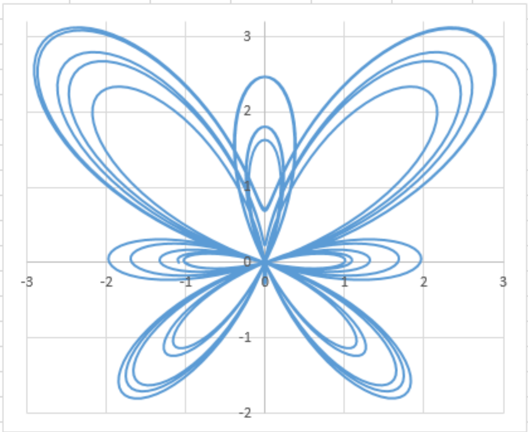
Appendix C. Implementation of "butterfly" curve in Matlab program environment and MS Excel

```
tic; clc, clear all, close all
theta=[0:pi/64:10*pi]
r=exp(sin(theta))-2*cos(4*theta)-(sin((2*theta-pi)/24)).^5
x=r.*cos(theta)
y=r.*sin(theta)
plot(x,y,'Color','b','linewidth',1)
grid on; axis equal; toc
```



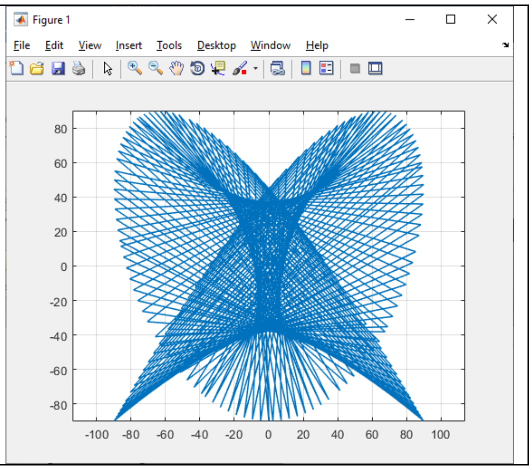
When realizing the figure of the "butterfly" in MS Excel, a value of 0 is written in cell with address B2. The formula is written in cell B3 =B2+PI()/64. This formula fills all cells from B3 to B642. The values of the radius r are calculated by =EXP(SIN(B2))-2*COS(4*B2)-(SIN((2*B2-PI())/24))^5. The coordinates of the points in Figures x and y are then calculated. To calculate x, the formula is =C2*COS(B2), for y, it is =C2*SIN(B2).

	A	B	C	D	E
1		theta	r	x	y
2		0,000	-1,000	-1,000	0,000
3		0,049	-0,911	-0,910	-0,045
4		0,098	-0,745	-0,741	-0,073
5		0,147	-0,505	-0,499	-0,074
6		0,196	-0,199	-0,195	-0,039
7		0,245	0,164	0,159	0,040
8		0,295	0,571	0,547	0,166
9		0,344	1,010	0,951	0,340
10		0,393	1,466	1,355	0,561
11		0,442	1,924	1,739	0,822
12		0,491	2,368	2,088	1,116
13		0,540	2,783	2,387	1,431
14		0,589	3,157	2,625	1,754
15		0,638	3,477	2,793	2,071
16		0,687	3,734	2,886	2,369
17		0,736	3,919	2,904	2,632
18		0,785	4,028	2,848	2,848

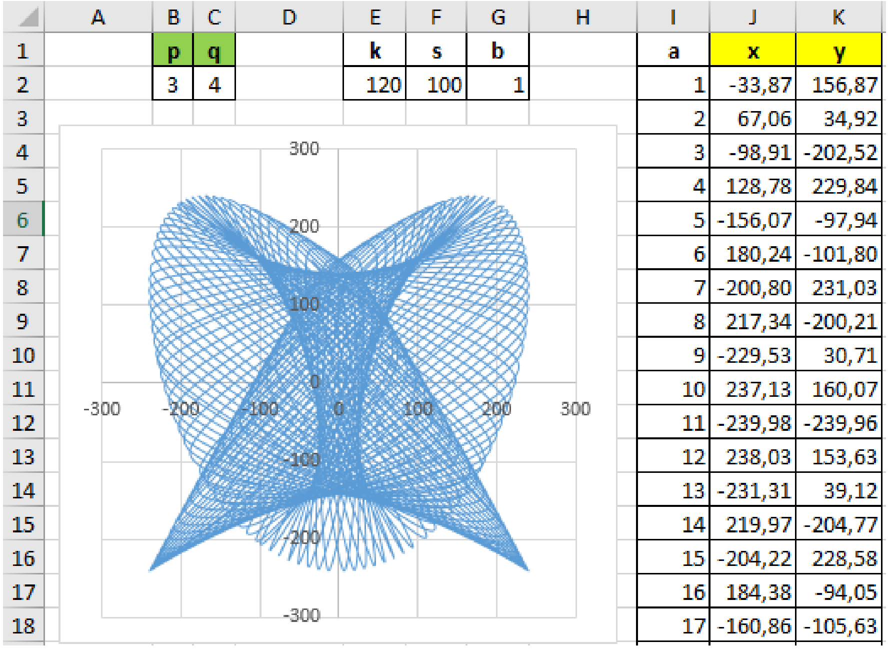


Appendix D. Implementation of Lissajous figure in Matlab program environment and MS Excel

```
tic; clc, clear all, close all
p=3; q=4; k=90; b=200
a=[1:b]
x=[(k*sin(p*a)) (k*sin(p*(a-1)))]
y=[(k*cos(q*a)) (k*cos(q*(a-1)))]
plot (-x,-y,'linewidth',1)
grid on; axis equal; toc
```



The values of the variables p and q are written in cells with addresses B2 and C2, respectively. The variables k, s and b are entered in cells E2, F2 and G2. The variable a changes its values in the interval [1, 200], which are sequentially entered in cells with addresses I2 to I201. The values of x and y, through which the figure is drawn, are entered as =-(($E$2*SIN($B$2*I2)*2)), for x, and =-(($E$2*COS($C$2*I2))*2), for y.



	A	B	C	D	E	F	G	H	I	J	K
1		p	q		k	s	b		a	x	y
2		3	4		120	100	1		1	-33,87	156,87
3									2	67,06	34,92
4									3	-98,91	-202,52
5									4	128,78	229,84
6									5	-156,07	-97,94
7									6	180,24	-101,80
8									7	-200,80	231,03
9									8	217,34	-200,21
10									9	-229,53	30,71
11									10	237,13	160,07
12									11	-239,98	-239,96
13									12	238,03	153,63
14									13	-231,31	39,12
15									14	219,97	-204,77
16									15	-204,22	228,58
17									16	184,38	-94,05
18									17	-160,86	-105,63

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