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THE STRAIGHT LINE AND ITS DIFFERENT DEFINITIONS.

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ANNOTATION.

D e card coordinate system be included in the plane . In this case, each point M on the plane is completely determined by a pair of numbers (*x* , *y)* called its ***coordinates*** d and written as M(*x* , *y*), as mentioned earlier . Each geometric object in the plane (line, geometric figure, etc.) can be viewed as a collection of points . In this case, the point M must satisfy a certain condition for it to belong to a line .

In plane analytic geometry, properties of lines are studied algebraically through their equations. The simplest and most common line is a straight line. You can see general, slope, section, normal, canonical and parametric equations of straight lines in the plane . These equations will be used later in solving various straight line problems.

DEFINITION 1: If the equation (*) is satisfied only by the coordinates of the points M(*x* , *y) belonging to a line L in the t* e region , it is called the ***equation of*** this ***line*** d e b.

If the condition $F(x_0, u_0) = 0$ is fulfilled for the point $M_0(x_0, u_0)$ (the equation is satisfied), the point M_0 belongs to the line defined by this equation, otherwise it does not belong. Thus, a line in a plane is completely determined by its equation. But not every equation necessarily represents a line. For example, the equation $x^2 + y^4 = 0$ is satisfied by only one O(0,0) point coordinates, and therefore this equation does not represent a line. Also, the equation $x^2 + y^2 + 1 = 0$ is not satisfied by the coordinates of any point in the plane, and it represents the empty set.

DEFINITION 2: ***The mathematical science that*** studies lines in a plane through their ***equations*** is called ***analytical geometry*** .

The founder of analytical geometry is the Farang mathematician and philosopher René Décart . Through the coordinate system introduced by him, a one-value correspondence was established between the point M, which is a geometric concept, and the pair of numbers (*x* , *y)* , which is an algebraic concept . This created a link between the two branches of mathematics, algebra and geometry. As a result, it was possible to easily solve a number of geometric problems in the plane algebraically and, conversely, a number of algebraic problems by geometric methods .

Analytical geometry in the plane mainly deals with two issues :

- Finding the equation of the given line and analytically studying it based on this equation .
- Determine the line that fits the given equation.

Problem: Find the equation of a circle with radius R centered at M (*a* , *b).*

Solution: Let N(*x* , *y*) be an arbitrary point on this circle. According to the definition of a circle familiar to us from school, it consists of a set of points satisfying the condition |MN|=R (ge om e trical locus). Then, according to the formula of the distance between two points, we create this equation of a circle :

$$|MN| = R \Rightarrow \sqrt{(x-a)^2 + (y-b)^2} = R \Rightarrow (x-a)^2 + (y-b)^2 = R^2 \quad (1)$$

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For example, a circle with center at M(2,3) and radius R=5 has equation $(x-2)^2 + (u-3)^{2 = 25.}$ From here it follows that the point N(5,7) belongs to this circle, because $(5-2)^2 + (7-3)^2 = 25$. The point K(2,6) does not lie on the circle, because its coordinates do not satisfy the equation of the circle:

$$(2-2)^2 + (6-3)^2 = 9 \ ^1\ 25.$$

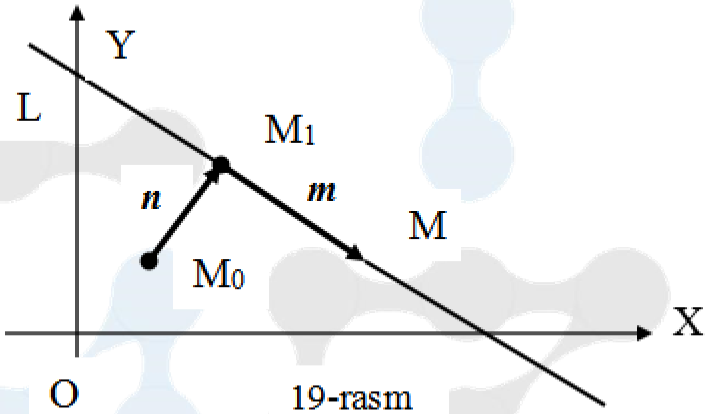
1. The general equation of a straight line in a plane. A straight line is one of the elementary concepts of geometry, which is taken without definition.

T E OR E MA: Any *L in the plane* equation of a straight line

$$A\,x + B\,y + C = 0\ ,\ A^2 + B^2 \neq 0\ (2)$$

in the form , that is, it consists of an equation of order I. Conversely, any I-order equation (2) represents a straight line in the plane .

Proof: First, we show that the first part of the theorem is valid. For this, the given *L of the plane* we get an arbitrary point M $_0$ that does not belong to a straight line (see Fig. 19).



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From this point, we draw a perpendicular to the straight line *L* and mark their point of intersection as $M_1(x_1, y_1)$. Let's enter the vector $\boldsymbol{n} \neq 0$ with the beginning M_0 and the end M_1 and take its coordinates as A and B, that is, $\boldsymbol{n}$ **= (A,B).** Now we take an arbitrary point $M(x, y)$ *lying* on the ***straight*** *line L* and m = $(x - x_1, y - y_1)$ we look at the vector. Here $M(x, y)$ is a point *L* if and only if ***n*** and ***m*** vectors are orthogonal. Using the expression of the condition of orthogonality of vectors in coordinates (Chapter III , § 2), we get the following results:

$$\boldsymbol{n}\cdot\boldsymbol{m} = A(x - x_1) + B(y - y_1) = 0 \Rightarrow A\,x + B\,y + (-A\,x_1 - B\,y_1) = 0 \Rightarrow A\,x + B\,y + C = 0.$$

Since $\boldsymbol{n} \neq \boldsymbol{0}$, | ***n*** | It follows that $^2 = A^2 + B^{2 \neq 0.}$

Now we prove the second part of the theorem, that is, we show that equation (2) represents a straight line. To do this, we write equation (2) in the following form :

$$A\,x + B\,y + C = A\,x + B(y + C/B) = 0\ Þ\ A\,(x - 0) + V\,(u - (-S/V)) = 0\ Þ\ A(x - x_1) + B(y - y_1) = 0.$$

Here $x_1 = 0$, $y_1 = -S/V$ designation was introduced. If we look at the vectors ***n*** = (A , V) and ***m*** =$(x - x_1, y - y_1)$, it follows from the last equality ***that n·m* = 0, that is, these vectors are orthogonal. The vertices** $M(x, y)$ *of all vectors* ***m* =(** $x - x_1, y - y_1$ **)** orthogonal to the vector ***n*** = (A , V) lie on one straight line. So, equation (2) represents a straight line passing through the point M 1 (0 , – S / V) and perpendicular to the vector ***n*** = (A , V) .

DEFINITION 3: Equation (2) is called ***the general equation of a*** straight line in a plane. In it, A and B are called ***coefficients*** , and C is called ***a free term*** .

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n =(A,B) **≠0** defined by equation (2) is perpendicular to the straight line *L* represented by this equation and is called its ***normal vector .***

For example, the equation 3 *x*+ 4 *y*– 8=0 represents a straight line passing through the point M 1 (0,2) and perpendicular to the vector n = ***(3,4***) .

Thus, we have established that any equation of a straight line is of the form (2) (Fundamental Problem I of analytic geometry), and conversely that any equation (2) represents a straight line (Fundamental Problem I of analytic geometry We have proved the main problem II).

Now we analyze some special cases of the general equation (2) of the straight line in the plane and draw conclusions.

2 . The equation of a **straight line in a plane with the slope coefficient.** The given straight line *L makes an angle* a (a ≠90 ^{0}) with the OX axis (that is, if the OX axis turns counterclockwise to an angle a , it is parallel to the straight line *L* will be) and let it be known that M 0 on the OY axis passes through the point (0, *b*) (see Fig. 20).

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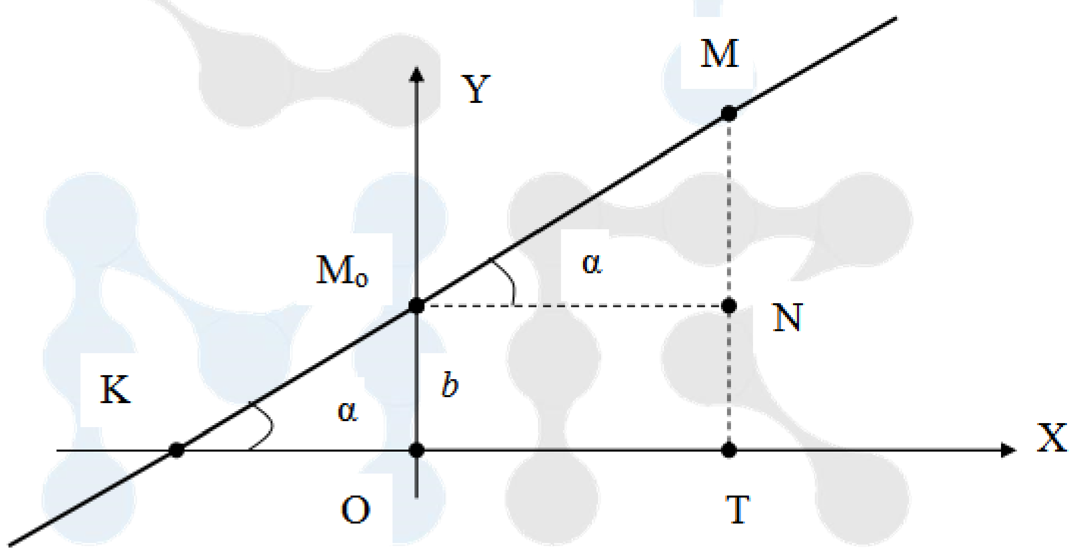

arbitrary point M(*x* , *y*) lying on this straight line satisfy. From the drawing

OM $_0$ =TN= *b* , OT=M $_0$ N= *x* , TM= *y* , $\angle M_0KO = \angle MM_0N = \alpha$

we see that Here D M $_0$ MN is a right triangle, from which we get the following result:

$$\frac{MN}{M_0N} = tg\alpha \Rightarrow \frac{TM - TN}{M_0N} = tg\alpha \Rightarrow \frac{y-b}{x} = tg\alpha \Rightarrow y - b = x \cdot tg\alpha \Rightarrow y = x \cdot tg\alpha + b.$$

By noting *tg* a = *k* in the last equation , we find that under the given conditions , the equation of a straight line *L has the following form:*

y=*kx*+*b* (3)

DEFINITION 4: (3) is called ***the equation of the straight line in the plane with the angle coefficient*** . Then *k*= *tg* a is ***the angle coefficient of the*** straight line , and *b* is called ***the starting ordinate .***

Note: If $L \perp OX$ if , then a =90 ^{0} and *k*= *tg* a will have no meaning. In this case, the equation of the vertical straight line *L* is *x* = *a* .

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If *L* If the general equation of a straight line is given by A *x*+ B *y* +C=0 (B≠0), then it is transferred to its angle coefficient equation as follows:

$$Ax + By + C = 0 \Rightarrow By = -Ax - C \Rightarrow y = -\frac{A}{B}x + (-\frac{C}{B}) \Rightarrow k = -\frac{A}{B}, \quad b = -\frac{C}{B}.$$

we find the slope equation of a straight line whose general equation is 4 *x* –6 *y* +3=0 :

$$4x - 6y + 3 = 0 \Rightarrow 6y = 4x + 3 \Rightarrow y = \frac{2}{3}x + \frac{1}{2} \Rightarrow k = \frac{2}{3}, \quad b = \frac{1}{2}.$$

3. The equation of a **straight line in a plane in sections. Let it be known that the straight line** *L*, which does not pass through the coordinate origin, intersects the coordinate axes OX and OY at the points M_1 (*a* ,0) and M_2 (0, *b*) , respectively . In this case, we find what the equation of *L* looks like .

To find the equation of this straight line M_1 (*a* ,0) v a We use the fact that the points M_2 (0, *b*) lie in it. The coordinates of these points *L* satisfies the general equation of a straight line A *x* + V *u* + S =0, i.e.

$$\begin{cases} Aa + B\cdot 0 + C = 0 \\ A\cdot 0 + Bb + C = 0 \end{cases} \Rightarrow \begin{cases} A = -\dfrac{C}{a} \\ B = -\dfrac{C}{b} \end{cases}$$

Here C≠0 because *L* a straight line does not pass through the coordinate origin.
Therefore, we get the following result from the general equation:

$$Ax + By + C = 0 \Rightarrow -\frac{C}{a}x + (-\frac{C}{b})y + C = 0 \Rightarrow -C(\frac{x}{a} + \frac{y}{b} - 1) = 0 \Rightarrow \frac{x}{a} + \frac{y}{b} - 1 = 0.$$

So, *L* the sought equation of a straight line

$$\frac{x}{a} + \frac{y}{b} = 1 \qquad (4)$$

appear . In this | *a* | and | *b* | *L represents the lengths of the section that separates the* considered straight line from the coordinate axes OX and OY, respectively. Therefore, the following definition is introduced.

DEFINITION 5: (4) is called the equation of a straight line ***in sections*** .

If *L does not pass through the coordinate origin* If a straight line is given by the general equation A *x* + V *u* + S =0 (A≠0, B≠0, C≠0), then to get to its cross section equation, multiply the general equation by (–C) divided into:

$$Ax + By + C = 0 \Rightarrow -\frac{A}{C}x + (-\frac{B}{C})y - 1 = 0 \Rightarrow \frac{x}{(-C/A)} + \frac{y}{(-C/B)} = 1.$$

For example, we find the equation of the straight line in sections with the general equation 2 *x* +3 *y*– 6= 0 :

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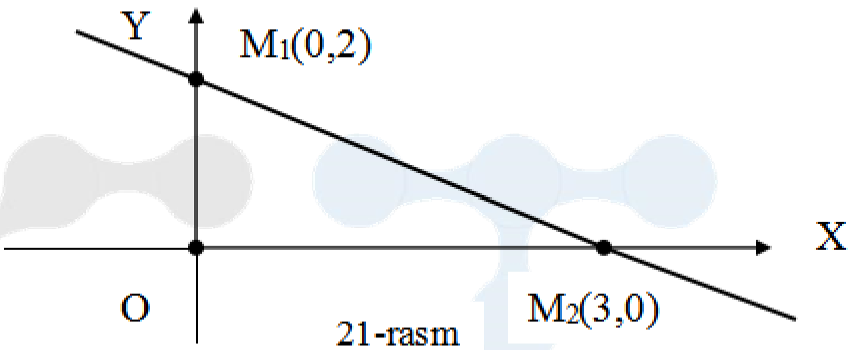
$$2x+3y-6=0 \Rightarrow \frac{2}{6}x+\frac{3}{6}y-1=0 \Rightarrow \frac{x}{3}+\frac{y}{2}=1.$$

Therefore, this straight line intersects the axes OX and OY at the points $M_1(3,0)$ and $M_2(0,2)$. Using this *L* a straight line can be easily constructed as follows (see Figure 21):



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4. Canonical equation of a straight line in a plane. Let there be a point $M_0(x_0, u_0)$ of the straight line *L* in the plane and a vector $\boldsymbol{a} = m\,\boldsymbol{i} + n\,\boldsymbol{j} = (m, n) \neq \boldsymbol{0}$ v ector parallel to it. In this case, the given point M_0 is v a ***a*** v e ctor *L* completely defines a straight line. Therefore, ***a* is *the direction vector of the*** straight line , and M_0 is called its ***initial point*** . Based on this information, *L* we define the equation of a straight line. For this, we take an arbitrary point $M(x, y)$ lying on the given straight line *L*. By connecting this point with the starting point M_0, we form the vector $\boldsymbol{x} = (x - x_0, u - u_0)$ v e ctor. According to the condition ***x*** v a ***a*** v e ctors are colline e ar . According to the condition of collinearity of vectors (see Chapter IV, § 3 , formula (5)), their corresponding coordinates are proportional:

$$\frac{x-x_0}{m}=\frac{y-y_0}{n} \qquad (7)$$

Note: If the direction vector of a straight line L =(m , n) m = 0 *(* L *-horizontal* straight *line)* or $n = 0$ (*L* -vertical straight line), then the pictures of the corresponding fractions in the equation (7) are taken as zero, and the equation of the straight line *L is written in the form* $y = y_0$ or $x = x_0$.

DEFINITION 7: (7) is called ***the canonical expression of a*** straight line in a plane .

The word "canonical" means simple, compact. If the straight line *L* is given by the general equation A *x*+ B *y*+ *C=0, then the* vector ***a*** =(B,–A) as the direction vector, the initial $M_0(x_0, u_0)$, and as a point, one can take an arbitrary point whose coordinates are $Ax_0 + Bu_0 = -C$, satisfying the condition. For example, $x_0 = 0$, $u_0 = -C/B$ or $x_0 = -C/A$, $u_0 = 0$ can be taken.

Explanation: If the straight line *L* is perpendicular to the axis OX or OY, that is, the straight line is perpendicular to the vector i or j, then n = 0 ***or*** *m = 0* . In this case, the image of the corresponding fraction in equation (7) is taken to be equal to zero, and the canonical equation of the straight line *L is of the form* $x=x_0$ or $y=y_0$, respectively .

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5. Parametric equation of a straight line in a plane. The values of the fractions in the canonical equation of the straight line (7) M(x , y) change when the point moves along the straight line and can be equal to an arbitrary real number t . Therefore, this equation can be written as:

$$\frac{y-y_0}{m}=\frac{x-x_0}{n}=t\Rightarrow\begin{cases}y-y_0=mt\\x-x_0=nt\end{cases}\Rightarrow\begin{cases}y=y_0+mt\\x=x_0+nt\end{cases},t\in(-\infty,\infty). \qquad (8)$$

DEFINITION 8: t is ***a parameter*** in the system (8) , and the system itself is called ***a parametric equation*** of a straight line in the plane .

If the straight line is given by the general equation A x+ B y+ C=0 (A≠0, B≠0), we take x = t *to pass to its parametric equation.* From this we arrive at the following parametric equation of a straight line:

$$\begin{cases}x=t\\y=-\frac{A}{B}t-\frac{C}{B}\end{cases}.$$

Note: If A=0 or B=0 in the general equation , (8) is a parametric equation

$$\begin{cases}x=t\\y=-\frac{C}{B}\end{cases}\quad \textbf{yoki} \quad \begin{cases}x=-\frac{C}{A}\\y=t\end{cases}$$

is written in the form

In solving various problems related to a straight line, its equation in one form or another can be convenient, and we will make sure of this later.

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