

# Динамическая система (устойчивый фокус)

$$\begin{cases} \frac{d}{dt}x = -2x - 2y \\ \frac{d}{dt}y = 8x - 2y \end{cases}$$

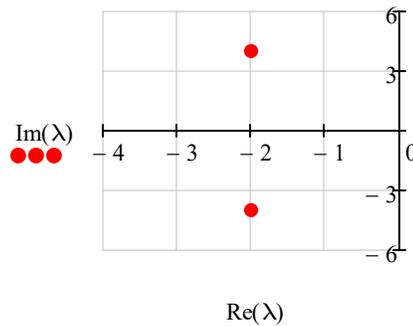
$$A := \begin{pmatrix} -2 & -2 \\ 8 & -2 \end{pmatrix} \quad a_1 := -\text{tr}(A) = 4 \quad a_2 := |A| = 20$$

$$V(a, z) := \begin{bmatrix} 0 \\ z \\ z + a \cdot e^{i \cdot (\arg(z) + 167 \cdot \text{deg})} \\ z - a \cdot 0.5 \cdot e^{i \cdot (\arg(z))} \\ z + a \cdot e^{i \cdot (\arg(z) - 167 \cdot \text{deg})} \\ z \end{bmatrix}$$

Корни характеристического уравнения - собственные числа матрицы A

$$z(p) := p^2 + a_1 \cdot p + a_2 \quad \lambda := z(p) \begin{cases} \text{solve, p} \\ \text{float, 4} \end{cases} \rightarrow \begin{pmatrix} -2.0 + 4.0i \\ -2.0 - 4.0i \end{pmatrix} \quad \text{eigenvals}(A) = \begin{pmatrix} -2 + 4i \\ -2 - 4i \end{pmatrix}$$

точки положения равновесия  
- устойчивый фокус



4 проверочные точки и вектор скорости

$$A \cdot \begin{pmatrix} 2 \\ 0 \end{pmatrix} = \begin{pmatrix} -4 \\ 16 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} -2 \\ 0 \end{pmatrix} = \begin{pmatrix} 4 \\ -16 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 0 \\ 1.81 \end{pmatrix} = \begin{pmatrix} -3.62 \\ -3.62 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 0 \\ -1.8 \end{pmatrix} = \begin{pmatrix} 3.6 \\ 3.6 \end{pmatrix}$$

a := 4 size of arrow wings

$$v_1 := \frac{V(a, -4 + 16j)}{15} + 2$$

$$v_2 := \frac{V(a, 4 - 16j)}{15} + -2$$

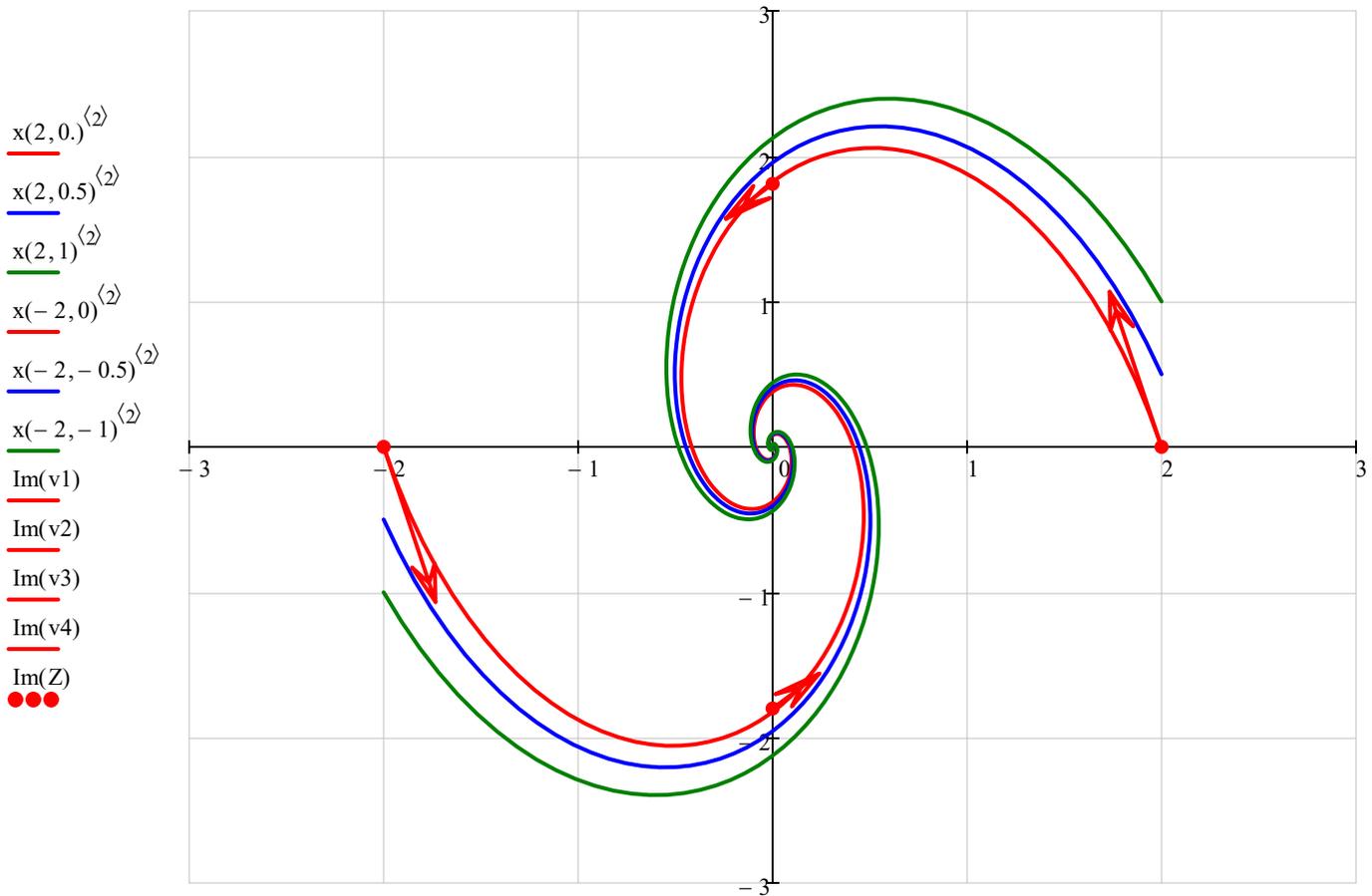
$$v_3 := \frac{V(a, -3.6 - 3.6j)}{15} + 1.81j$$

$$v_4 := \frac{V(a, 3.6 + 3.6j)}{15} + -1.8j$$

Z := (-2 2 j·1.81 -j·1.8)<sup>T</sup> точки в которых строится вектор скорости

метод пространство состояний

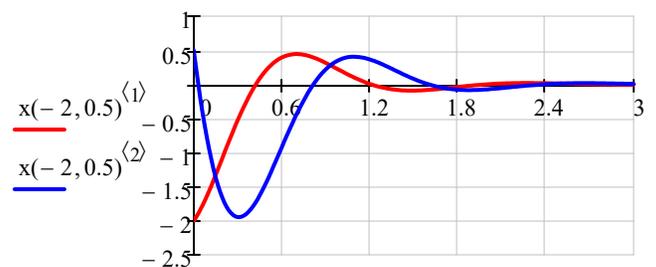
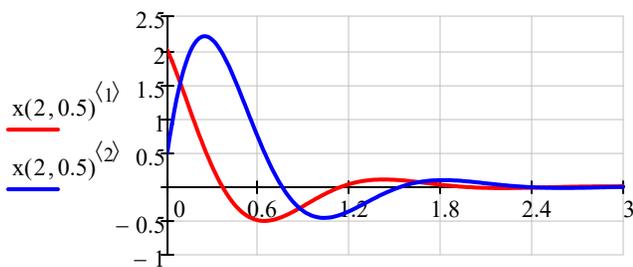
$$D(t, x) := A \cdot x \quad \underline{m}_w := 3 \quad \underline{N}_w := 200 \quad x(x_0, y_0) := \text{rkfixed} \left[ \begin{pmatrix} x_0 \\ y_0 \end{pmatrix}, 0, T, N, D \right]$$



- $x(2, 0)^{\langle 2 \rangle}$
- $x(2, 0.5)^{\langle 2 \rangle}$
- $x(2, 1)^{\langle 2 \rangle}$
- $x(-2, 0)^{\langle 2 \rangle}$
- $x(-2, -0.5)^{\langle 2 \rangle}$
- $x(-2, -1)^{\langle 2 \rangle}$
- Im(v1)
- Im(v2)
- Im(v3)
- Im(v4)
- Im(Z)
- 

$$x(2, 0)^{\langle 1 \rangle}, x(2, 0.5)^{\langle 1 \rangle}, x(2, 1)^{\langle 1 \rangle}, x(-2, 0)^{\langle 1 \rangle}, x(-2, -0.5)^{\langle 1 \rangle}, x(-2, -1)^{\langle 1 \rangle}, \text{Re}(v1), \text{Re}(v2), \text{Re}(v3), \text{Re}(v4), \text{Re}(Z)$$

### Зависимость от времени ( решение сходится)



$$x(2, 0.5)^{\langle 0 \rangle}$$

$$x(-2, 0.5)^{\langle 0 \rangle}$$

## Динамическая система (центр)

$$\begin{cases} \frac{d}{dt}x = 2x - 2y \\ \frac{d}{dt}y = 8x - 2y \end{cases}$$

$$A := \begin{pmatrix} 2 & -3 \\ 2 & -2 \end{pmatrix}$$

$$\underline{a}_{1w} := -\text{tr}(A) = 0$$

$$\underline{a}_{2w} := |A| = 2$$

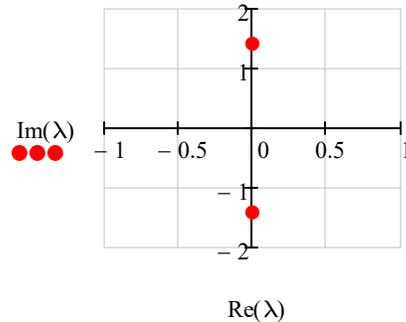
## Корни характеристического уравнения - собственные числа матрицы A

$$z(p) := p^2 + a_1 \cdot p + a_2$$

$$\lambda := z(p) \begin{cases} \text{solve, p} \\ \text{float, 4} \end{cases} \rightarrow \begin{pmatrix} 1.414i \\ -1.414i \end{pmatrix}$$

$$\text{eigenvals}(A) = \begin{pmatrix} 1.414i \\ -1.414i \end{pmatrix}$$

**точка положения равновесия - центр**



### Метод пространства состояний

$$\begin{matrix} \underline{D}(t, x) := A \cdot x & \underline{T} := 5 & \underline{N} := 200 & \underline{x}(x_0, y_0) := \text{rkfixed} \left[ \begin{pmatrix} x_0 \\ y_0 \end{pmatrix}, 0, T, N, D \right] \end{matrix}$$

### 4 проверочные точки и вектор скорости

$$A \cdot \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} 2 \\ 2 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} -1 \\ 0 \end{pmatrix} = \begin{pmatrix} -2 \\ -2 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} -3 \\ -2 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 0 \\ -1 \end{pmatrix} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$$

$$\underline{a} := 0.4 \quad \text{size of arrow wings}$$

$$z1 := V(a, 1 + i \cdot 1) + 1.21$$

$$z2 := V(a, -1 - i \cdot 1) - 1.21$$

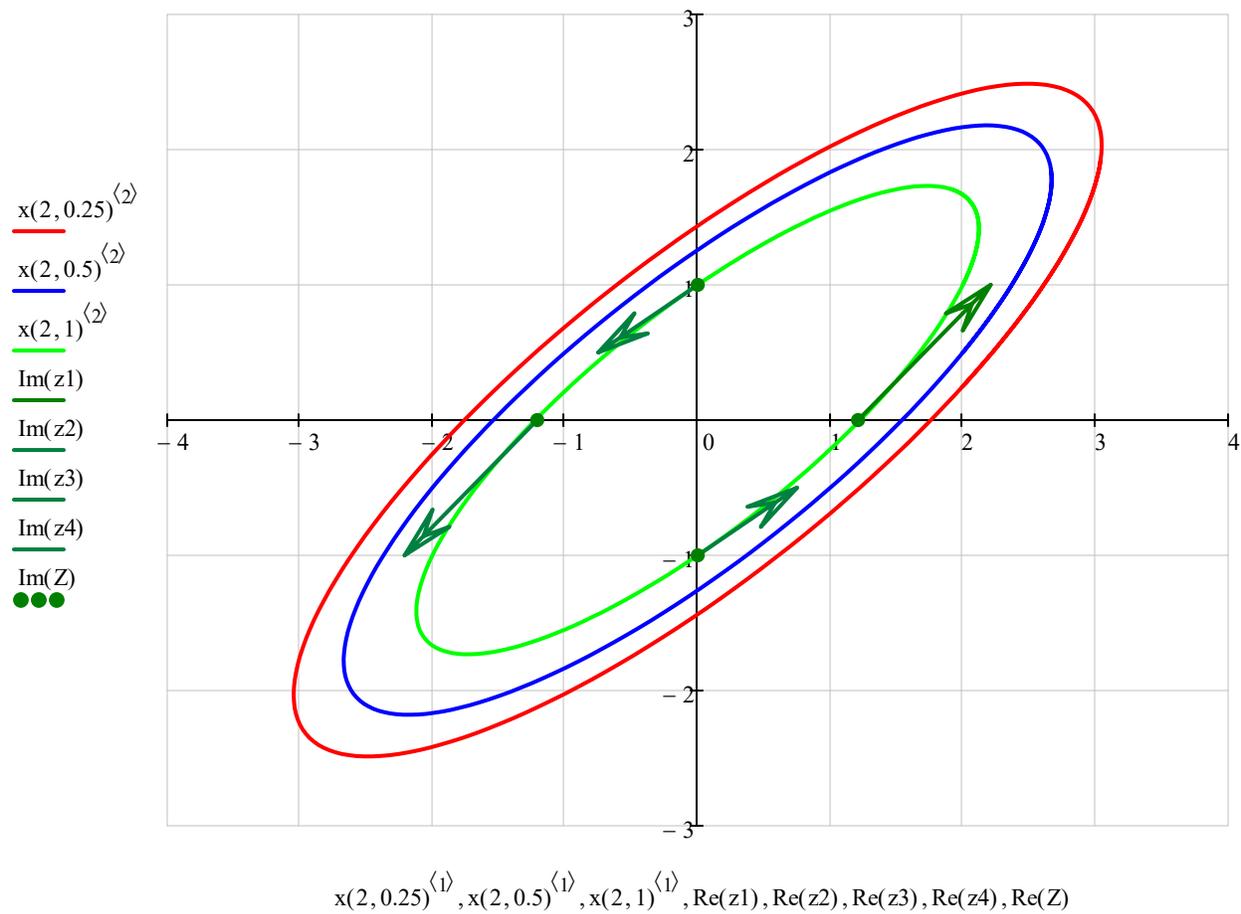
$$z3 := V(a, -0.75 - i \cdot 0.5) + i \cdot 1$$

$$z4 := V(a, 0.75 + i \cdot 0.5) - i \cdot 1$$

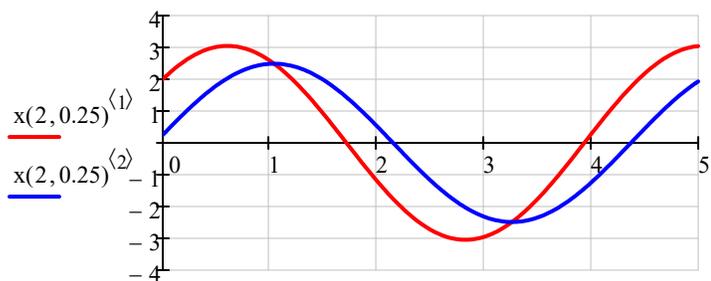
$$Z := (1.21 \quad -1.21 \quad i \quad -i)^T$$

**точки в которых строится вектор скорости**

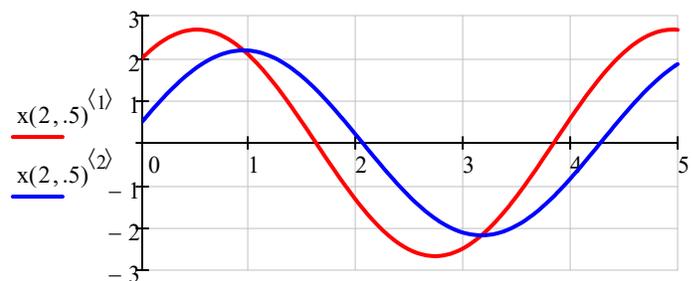
## Фазовый портрет динамической системы



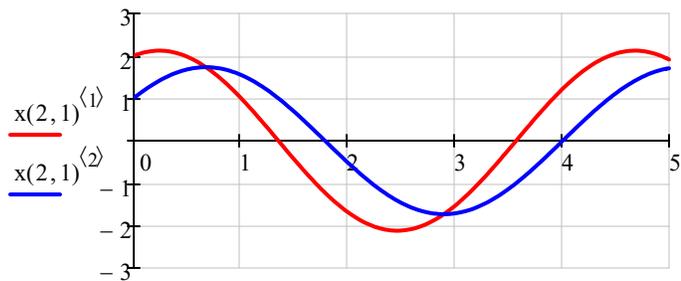
## Зависимость от времени ( решение сходится)



$x(2, 0.25)^{(0)}$



$x(2, 0.5)^{(0)}$



$x(2, 1)^{(0)}$

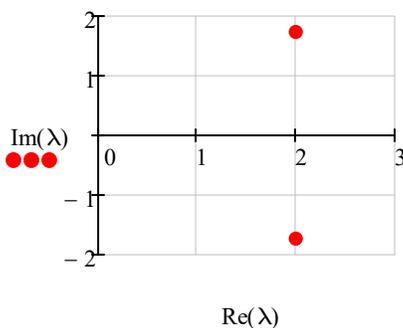
# Динамическая система (unstable spiral- не устойчивый фокус)

$$\begin{cases} \frac{d}{dt}x = 2x - 1y \\ \frac{d}{dt}y = 3x + 2y \end{cases}$$

$$A := \begin{pmatrix} 2 & -1 \\ 3 & 2 \end{pmatrix} \quad a_{11} := -\text{tr}(A) = -4 \quad a_{22} := |A| = 7$$

Корни характеристического уравнения - собственные числа матрицы A

$$z(p) := p^2 + a_1 \cdot p + a_2 \quad \lambda := z(p) \begin{cases} \text{solve, p} \\ \text{float, 4} \end{cases} \rightarrow \begin{pmatrix} 2.0 + 1.732i \\ 2.0 - 1.732i \end{pmatrix} \quad \text{eigenvals}(A) = \begin{pmatrix} 2 + 1.732i \\ 2 - 1.732i \end{pmatrix}$$



точка положения равновесия  
- не устойчивый фокус

## 4 проверочные точки и вектор скорости

$$A \cdot \begin{pmatrix} 0 \\ 2.1 \end{pmatrix} = \begin{pmatrix} -2.1 \\ 4.2 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 0 \\ -2.1 \end{pmatrix} = \begin{pmatrix} 2.1 \\ -4.2 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 0.2 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.4 \\ 0.6 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} -0.2 \\ 0 \end{pmatrix} = \begin{pmatrix} -0.4 \\ -0.6 \end{pmatrix}$$

$a := 1.5$  size of arrow wings

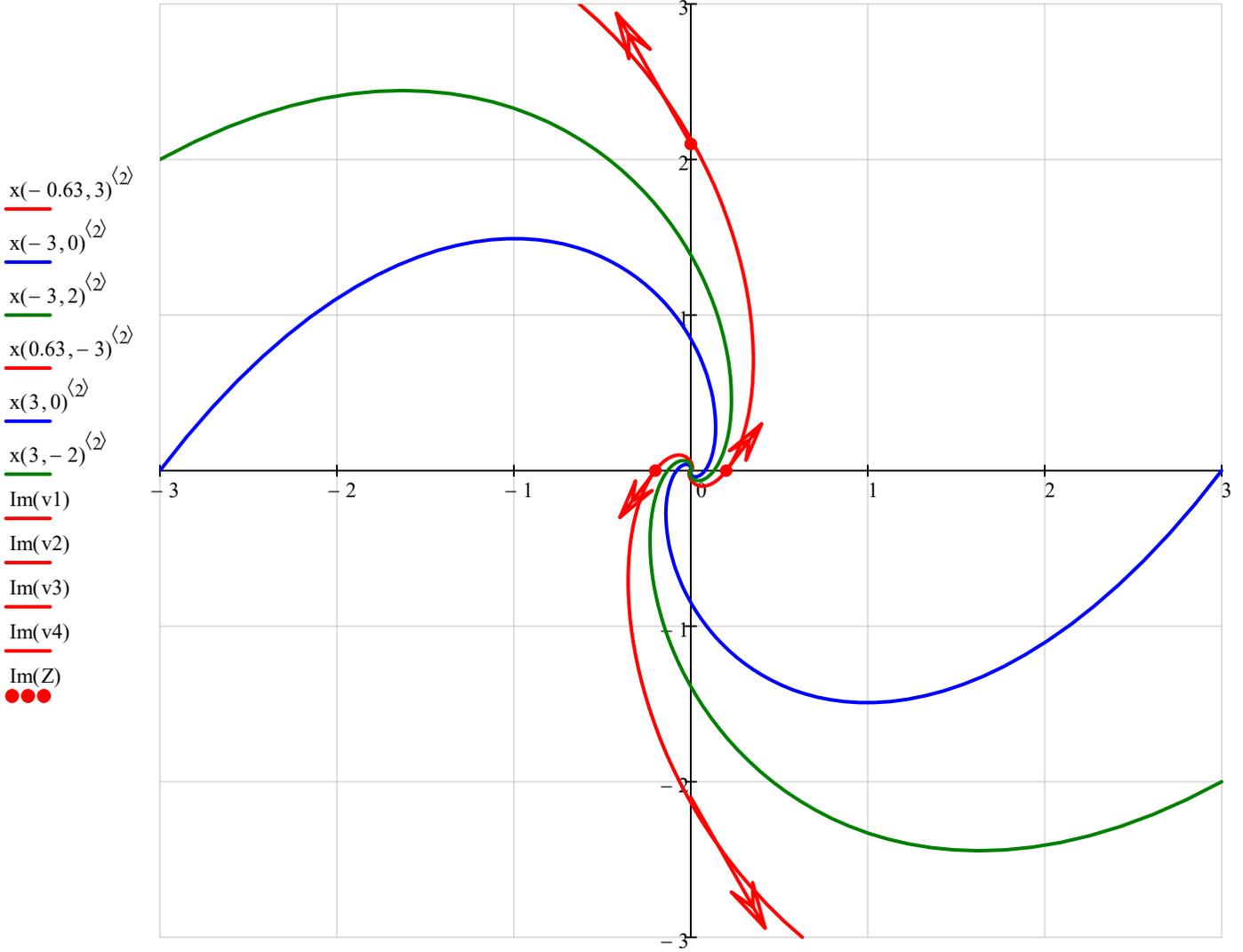
$$\begin{aligned} v1 &:= \frac{V(a, -2.1 + 4.2j)}{5} + 2.1j & v2 &:= \frac{V(a, 2.1 - 4.2j)}{5} - 2.1j & v3 &:= \frac{V\left(\frac{a}{3}, 0.4 + 0.6j\right)}{2} + 0.2 & v4 &:= \frac{V\left(\frac{a}{3}, -0.4 - 0.6j\right)}{2} - 0.2 \end{aligned}$$

$Z := (2.1j \ 2.1j \ 0.2 \ -0.2)^T$  points where we draw the velocity vectors

The direction of the velocity shows that solution diverges

# State space technique

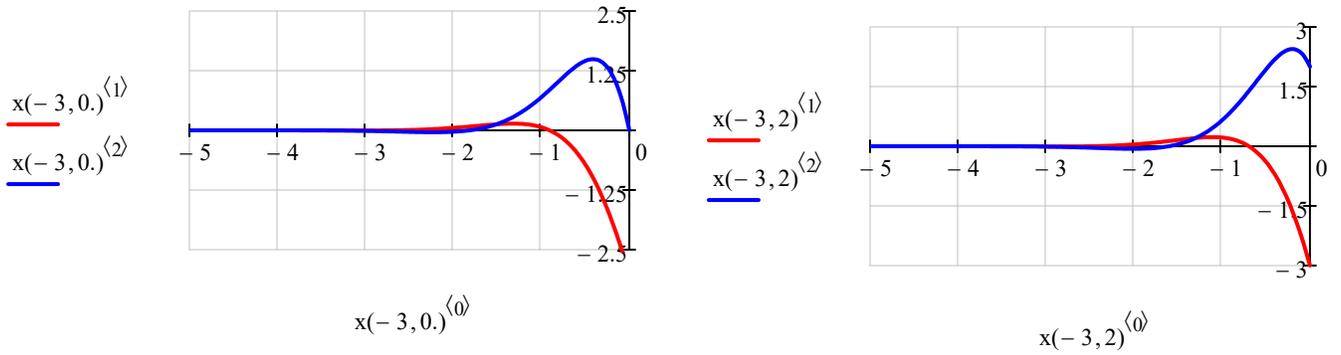
$$D(t, x) := A \cdot x \quad T := 5 \quad N := 200 \quad \underline{x}(x_0, y_0) := \text{rkfixed} \left[ \begin{pmatrix} x_0 \\ y_0 \end{pmatrix}, 0, -T, N, D \right]$$



- $x(-0.63, 3)^{(2)}$
- $x(-3, 0)^{(2)}$
- $x(-3, 2)^{(2)}$
- $x(0.63, -3)^{(2)}$
- $x(3, 0)^{(2)}$
- $x(3, -2)^{(2)}$
- $\text{Im}(v1)$
- $\text{Im}(v2)$
- $\text{Im}(v3)$
- $\text{Im}(v4)$
- $\text{Im}(Z)$
- 

$x(-0.63, 3)^{(1)}, x(-3, 0)^{(1)}, x(-3, 2)^{(1)}, x(0.63, -3)^{(1)}, x(3, 0)^{(1)}, x(3, -2)^{(1)}, \text{Re}(v1), \text{Re}(v2), \text{Re}(v3), \text{Re}(v4), \text{Re}(Z)$

## Time dependance of variables (solution diverges)



$x(-3, 0)^{(0)}$

$x(-3, 2)^{(0)}$

# Динамическая система (седло)

$$\begin{cases} \frac{d}{dt}x = x - y \\ \frac{d}{dt}y = -3x - y \end{cases}$$

$$A := \begin{pmatrix} 1 & -1 \\ -3 & -1 \end{pmatrix} \quad \text{eigenvals}(A) = \begin{pmatrix} 2 \\ -2 \end{pmatrix}$$

$$a_1 := -\text{tr}(A) = 0 \quad a_2 := |A| = -4$$

## Корни характеристического уравнения

$$z(p) := p^2 + a_1 \cdot p + a_2 \quad \lambda := z(p) \begin{cases} \text{solve} \\ \text{float}, 5 \end{cases} \rightarrow \begin{pmatrix} 2.0 \\ -2.0 \end{pmatrix}$$

## Точка положения равновесия - седло

## Находим собственный вектор и сепаратрису

1)  $A := \begin{pmatrix} 1 & -1 \\ -3 & -1 \end{pmatrix} \quad \begin{pmatrix} 1 - \lambda_0 & -1 \\ -3 & -1 - \lambda_0 \end{pmatrix} = \begin{pmatrix} -1 & -1 \\ -3 & -3 \end{pmatrix}$  решаем для любой строки

$$-a_1 \cdot 1 = a_2 \cdot 1 \quad \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} := \begin{pmatrix} -1 \\ 1 \end{pmatrix}$$

$$v_1 := \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} -1 \\ 1 \end{pmatrix} \quad \text{точка на сепаратрисе. ее нужно соединить с началом координат}$$

аналогично используется другая точка  $-v_1 = \begin{pmatrix} 1 \\ -1 \end{pmatrix}$

$$s_1 := \begin{pmatrix} -1 + j \\ 1 - j \end{pmatrix} \cdot 3 \quad 3 - \text{ масштабный коэффициент}$$

2)  $\begin{pmatrix} 1 - \lambda_1 & -1 \\ -3 & -1 - \lambda_1 \end{pmatrix} = \begin{pmatrix} 3 & -1 \\ -3 & 1 \end{pmatrix} \quad a_1 \cdot 3 = a_2 \cdot 1 \quad \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} := \begin{pmatrix} 1 \\ 3 \end{pmatrix} \quad v_2 := \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} 1 \\ 3 \end{pmatrix}$

**separatrix**

$$s_1 := \begin{pmatrix} -1 + j \\ 1 - j \end{pmatrix} \cdot 3 \quad s_2 := \begin{pmatrix} 1 + 3j \\ -1 - 3j \end{pmatrix} \cdot 3$$

## 4 test points and vectors

$$A \cdot \begin{pmatrix} -2 \\ 2 \end{pmatrix} = \begin{pmatrix} -4 \\ 4 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 2 \\ -2 \end{pmatrix} = \begin{pmatrix} 4 \\ -4 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} 0.32 \\ 1 \end{pmatrix} = \begin{pmatrix} -0.68 \\ -1.96 \end{pmatrix}$$

$$A \cdot \begin{pmatrix} -1 \\ -0.32 \end{pmatrix} = \begin{pmatrix} -0.68 \\ 3.32 \end{pmatrix}$$

$$\underline{\underline{a}} := 1.5$$

$$v1 := \frac{V(a, -4 + 4j)}{6} + 1j - 1$$

$$\underline{\underline{v3}} := \frac{V\left(\frac{a}{3}, -0.68 - 1.96j\right)}{2.5} + 0.33 + j$$

$$\underline{\underline{v4}} := \frac{V\left(\frac{a}{3}, 0.68 + 1.96j\right)}{2.5} - 0.33 - j$$

$$v2 := \frac{V(a, 4 - 4j)}{6} - 1j + 1$$

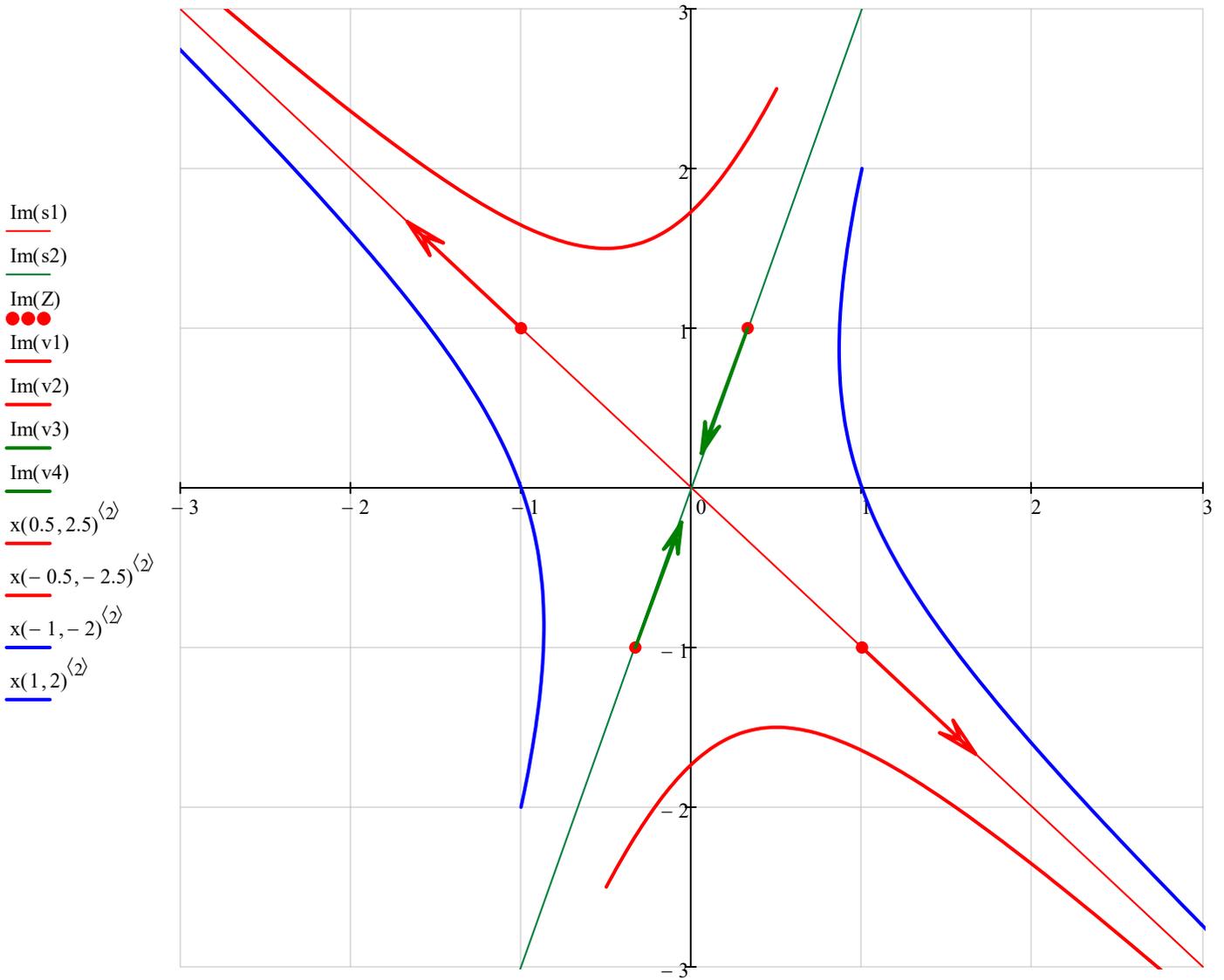
$$\underline{\underline{D}}(t, x) := A \cdot x$$

$$\underline{\underline{T}} := 2$$

$$\underline{\underline{N}} := 200$$

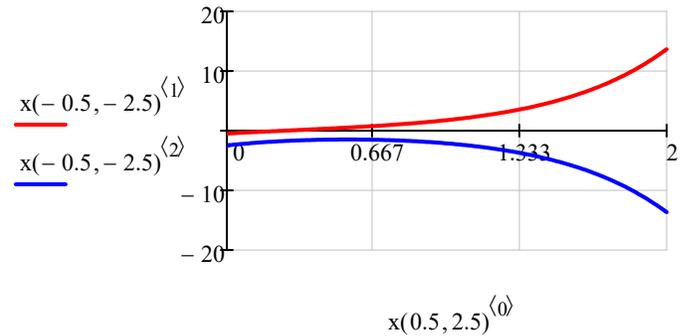
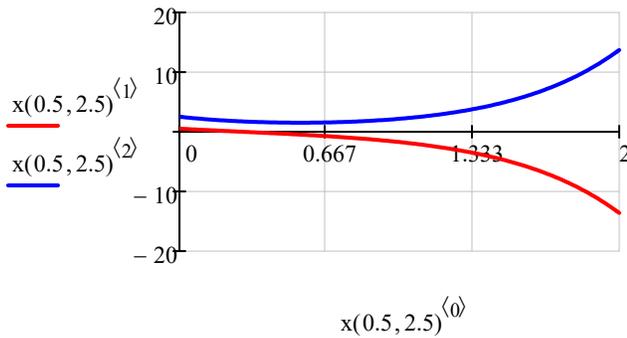
$$\underline{\underline{x}}(x_0, y_0) := \text{rkfixed}\left[\begin{pmatrix} x_0 \\ y_0 \end{pmatrix}, 0, T, N, D\right]$$

$$Z := [-1 + 1j \quad 1 - 1j \quad 0.33 + j \quad -(0.33 + j)]^T$$



$$\text{Re}(s1), \text{Re}(s2), \text{Re}(Z), \text{Re}(v1), \text{Re}(v2), \text{Re}(v3), \text{Re}(v4), x(0.5, 2.5)^{\langle 1 \rangle}, x(-0.5, -2.5)^{\langle 1 \rangle}, x(-1, -2)^{\langle 1 \rangle}, x(1, 2)^{\langle 1 \rangle}$$

## Time dependance of variables (some solutions converge , others diverge)



## Dynamic system (устойчивый узел)

$$\begin{cases} \frac{d}{dt}x = -4x + y \\ \frac{d}{dt}y = x - 4y \end{cases}$$

$$A := \begin{pmatrix} -4 & 1 \\ 1 & -4 \end{pmatrix}$$

$$\lambda := \text{eigenvals}(A) = \begin{pmatrix} -5 \\ -3 \end{pmatrix}$$

$$a_{1w} := -\text{tr}(A) = 8$$

$$a_{2w} := |A| = 15$$

### Корни характеристического уравнения

$$z(p) := p^2 + a_1 \cdot p + a_2 \quad \lambda := z(p) \left| \begin{array}{l} \text{solve} \\ \text{float}, 5 \end{array} \right. \rightarrow \begin{pmatrix} -3.0 \\ -5.0 \end{pmatrix}$$

### Точка положения равновесия - устойчивый узел

#### finding eigenvectors and separatrix

#### 1) solution for test vector v1

$$A := \begin{pmatrix} -4 & 1 \\ 1 & -4 \end{pmatrix} \quad \begin{pmatrix} -4 - \lambda_0 & 1 \\ 1 & -4 - \lambda_0 \end{pmatrix} = \begin{pmatrix} -1 & 1 \\ 1 & -1 \end{pmatrix} \quad a_1 \cdot 1 = a_2 \cdot 1 \quad \begin{pmatrix} a_{1w} \\ a_{2w} \end{pmatrix} := \begin{pmatrix} 1 \\ 1 \end{pmatrix}$$

$$v1 := \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix} \quad \text{и} \quad -v1 = \begin{pmatrix} -1 \\ -1 \end{pmatrix}$$

#### 2) solution for test vector v2

$$\begin{pmatrix} -4 - \lambda_1 & 1 \\ 1 & -4 - \lambda_1 \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix} \quad a_1 \cdot 1 = -a_2 \cdot 1 \quad \begin{pmatrix} a_{1w} \\ a_{2w} \end{pmatrix} := \begin{pmatrix} -1 \\ 1 \end{pmatrix}$$

$$\underline{\underline{v2}} := \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} -1 \\ 1 \end{pmatrix} \quad \text{и} \quad -v2 = \begin{pmatrix} 1 \\ -1 \end{pmatrix}$$

**separatrix**

$$\underline{\underline{s1}} := \begin{pmatrix} -1 + j \\ 1 - j \end{pmatrix} \cdot 3 \quad \underline{\underline{s2}} := \begin{pmatrix} 1 + j \\ -1 - j \end{pmatrix} \cdot 3 \quad \text{3 масштабный коэффициент}$$

$$\underline{\underline{D}}(t, x) := A \cdot x \quad \underline{\underline{T}} := 5 \quad \underline{\underline{N}} := 100 \quad \underline{\underline{x}}(x_0, y_0) := \text{rkfixed} \left[ \begin{pmatrix} x_0 \\ y_0 \end{pmatrix}, 0, T, N, D \right]$$

**4 test points**

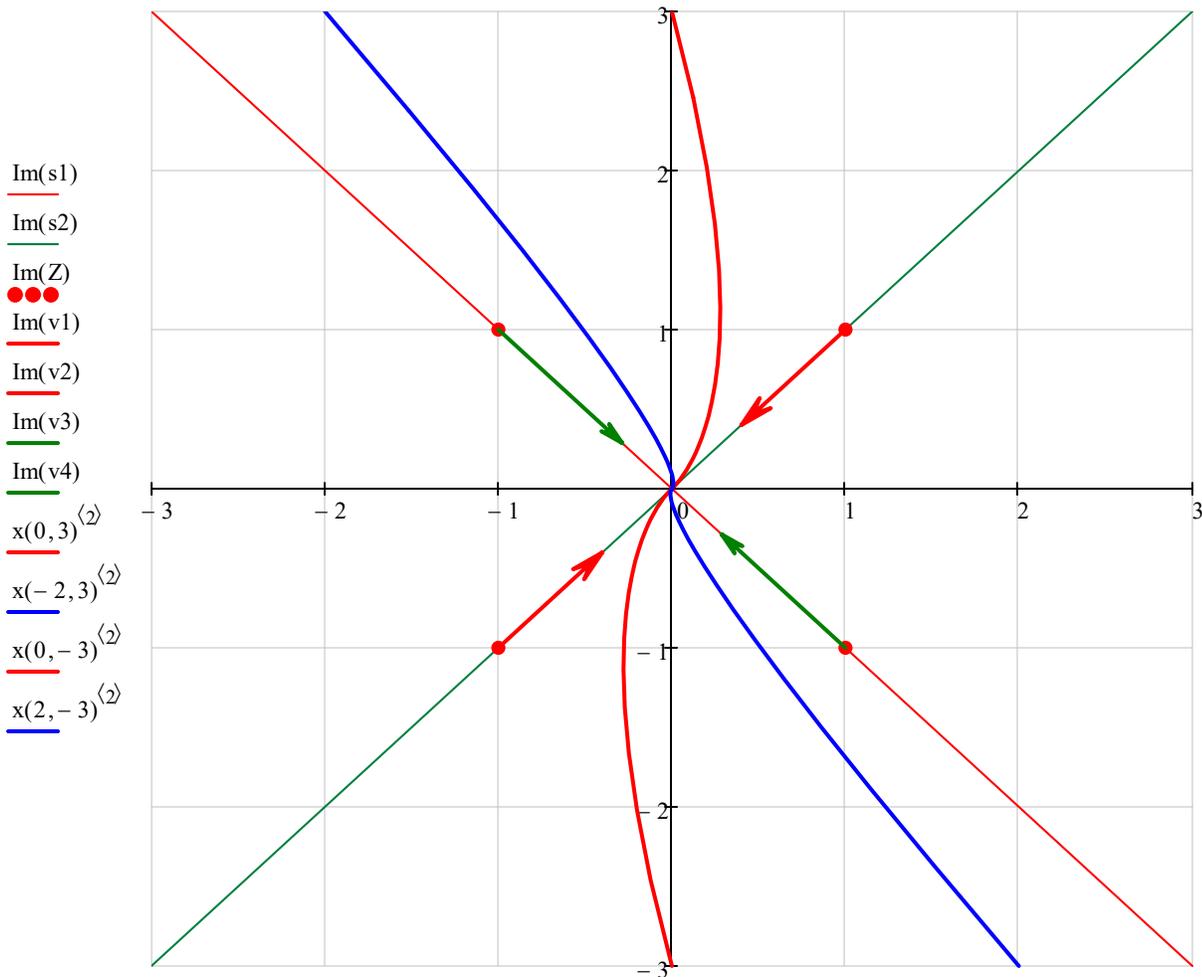
$$A \cdot \begin{pmatrix} 1 \\ 1 \end{pmatrix} = \begin{pmatrix} -3 \\ -3 \end{pmatrix} \quad A \cdot \begin{pmatrix} -1 \\ -1 \end{pmatrix} = \begin{pmatrix} 3 \\ 3 \end{pmatrix} \quad A \cdot \begin{pmatrix} -1 \\ 1 \end{pmatrix} = \begin{pmatrix} 5 \\ -5 \end{pmatrix} \quad A \cdot \begin{pmatrix} 1 \\ -1 \end{pmatrix} = \begin{pmatrix} -5 \\ 5 \end{pmatrix}$$

$$\underline{\underline{a}} := 1$$

**Test points and velocity vectors**

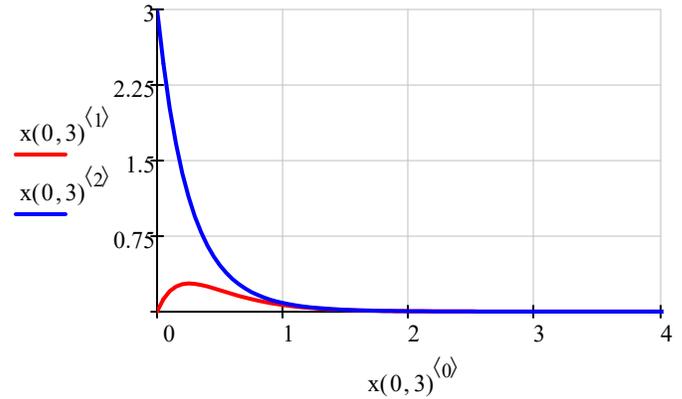
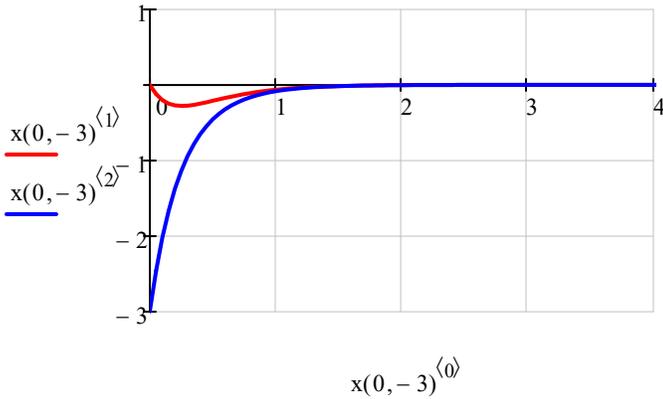
$$\underline{\underline{v1}} := \frac{V(a, -3 - i \cdot 3)}{5} + 1 + j \quad \underline{\underline{v2}} := \frac{V(a, 3 + i \cdot 3)}{5} - (1 + j) \quad \underline{\underline{v3}} := \frac{V(a, 5 - i \cdot 5)}{7} + (-1 + j) \quad \underline{\underline{v4}} := \frac{V(a, -5 + i \cdot 5)}{7} + (1 - j)$$

$$Z := (1 + j \quad -1 - j \quad -1 + i \cdot 1 \quad 1 - i)^T$$



$$\text{Re}(s1), \text{Re}(s2), \text{Re}(Z), \text{Re}(v1), \text{Re}(v2), \text{Re}(v3), \text{Re}(v4), x(0, 3)^{(1)}, x(-2, 3)^{(1)}, x(0, -3)^{(1)}, x(2, -3)^{(1)}$$

## Time dependance of variables (solution converges)



## Dynamic system (stable node)

$$\begin{cases} \frac{d}{dt}x = 2x - 7y \\ \frac{d}{dt}y = 3x - 8y \end{cases}$$

$$A := \begin{pmatrix} 2 & -7 \\ 3 & -8 \end{pmatrix}$$

$$\lambda := \text{eigenvals}(A) = \begin{pmatrix} -1 \\ -5 \end{pmatrix}$$

$$a_1 := -\text{tr}(A) = 6$$

$$a_2 := |A| = 5$$

### Roots of characteristic equation

$$z(p) := p^2 + a_1 \cdot p + a_2$$

$$\lambda := z(p) \begin{cases} \text{solve} \\ \text{float}, 5 \end{cases} \rightarrow \begin{pmatrix} -1.0 \\ -5.0 \end{pmatrix}$$

точка положения равновесия - седло

### finding eigenvectors and separatrix

#### 1) solution for test vector v1

$$A := \begin{pmatrix} 2 & -7 \\ 3 & -8 \end{pmatrix}$$

$$\begin{pmatrix} 2 - \lambda_0 & -7 \\ 3 & -8 - \lambda_0 \end{pmatrix} = \begin{pmatrix} 3 & -7 \\ 3 & -7 \end{pmatrix}$$

$$a_1 \cdot 1 = a_2 \cdot 1$$

$$\begin{pmatrix} a_1 \\ a_2 \end{pmatrix} := \begin{pmatrix} 7 \\ 3 \\ 1 \end{pmatrix}$$

$$v1 := \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} 2.333 \\ 1 \end{pmatrix}$$

#### 2) solution for test vector v2

$$\begin{pmatrix} 2 - \lambda_1 & -7 \\ 3 & -8 - \lambda_1 \end{pmatrix} = \begin{pmatrix} 7 & -7 \\ 3 & -3 \end{pmatrix}$$

$$a_1 \cdot 1 = a_2 \cdot 1$$

$$\begin{pmatrix} a_1 \\ a_2 \end{pmatrix} := \begin{pmatrix} 1 \\ 1 \end{pmatrix}$$

$$v2 := \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$$

$$\lambda = \begin{pmatrix} -1 \\ -5 \end{pmatrix}$$

# separatrix

$$s1 := \begin{pmatrix} 2.33 + j \\ -2.33 - j \end{pmatrix} \cdot 3 \quad s2 := \begin{pmatrix} 1 + j \\ -1 - j \end{pmatrix} \cdot 3$$

$$D(t, x) := A \cdot x \quad T := 5 \quad N := 100 \quad x(x_0, y_0) := \text{rkfixed} \left[ \begin{pmatrix} x_0 \\ y_0 \end{pmatrix}, 0, T, N, D \right]$$

## 4 test points

$$A \cdot \begin{pmatrix} 1 \\ 1 \end{pmatrix} = \begin{pmatrix} -5 \\ -5 \end{pmatrix} \quad A \cdot \begin{pmatrix} -1 \\ -1 \end{pmatrix} = \begin{pmatrix} 5 \\ 5 \end{pmatrix} \quad A \cdot \begin{pmatrix} 2.33 \\ 1 \end{pmatrix} = \begin{pmatrix} -2.34 \\ -1.01 \end{pmatrix} \quad A \cdot \begin{pmatrix} -2.33 \\ -1 \end{pmatrix} = \begin{pmatrix} 2.34 \\ 1.01 \end{pmatrix}$$

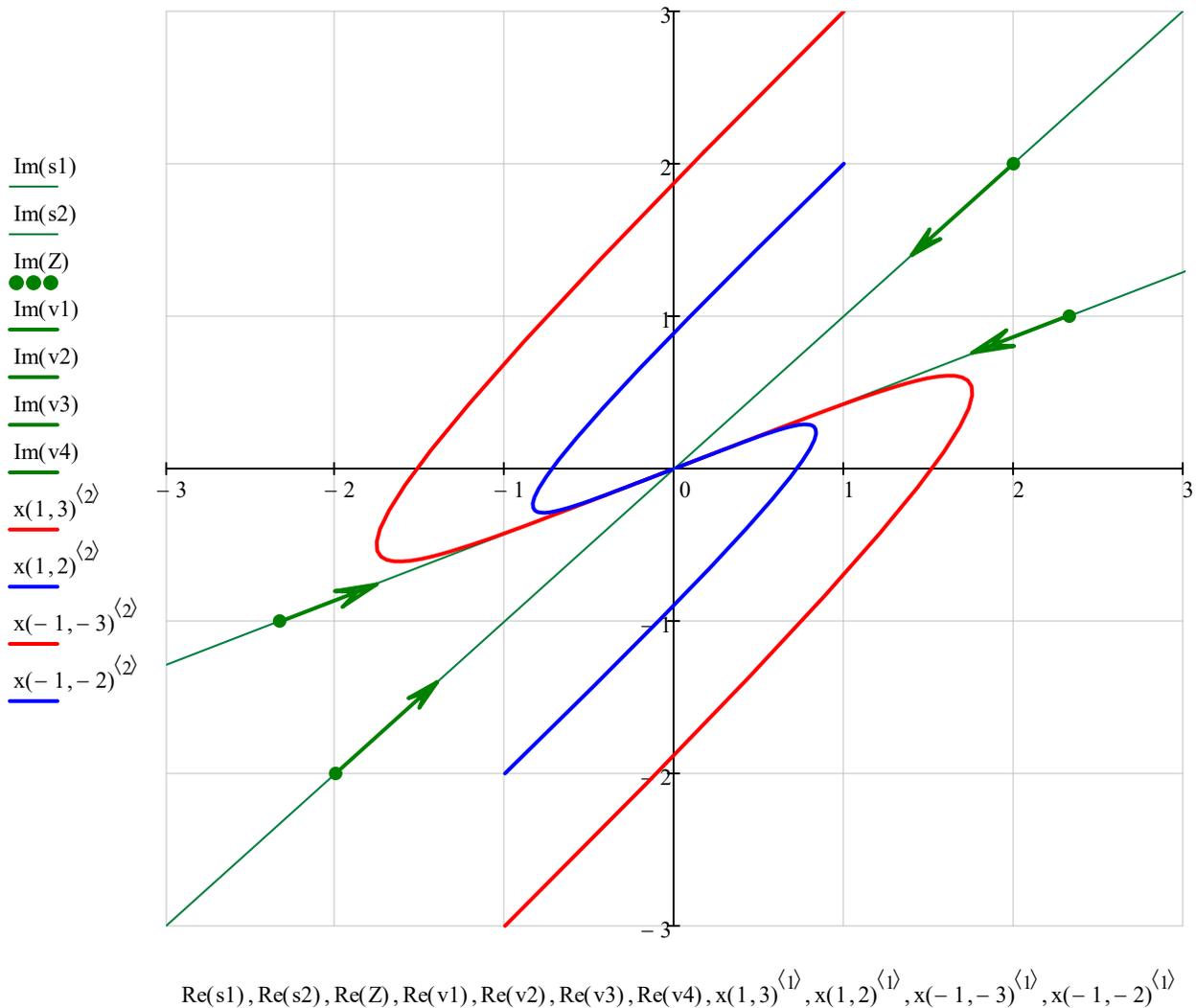
$$a := 1$$

## Test vectors(velocity) forming

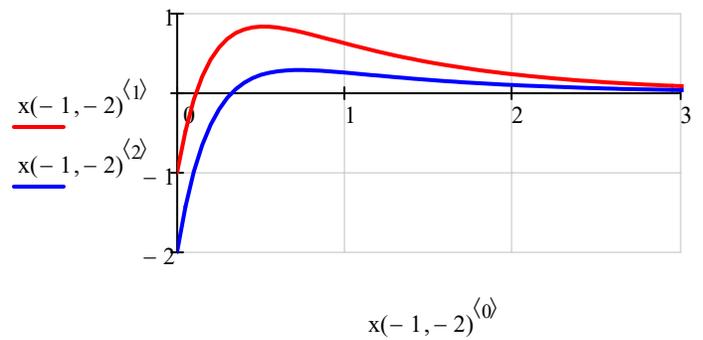
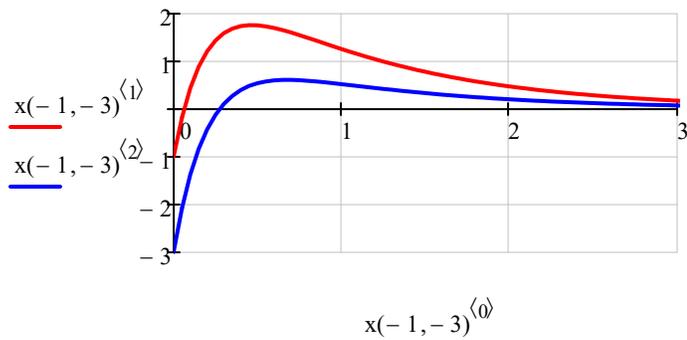
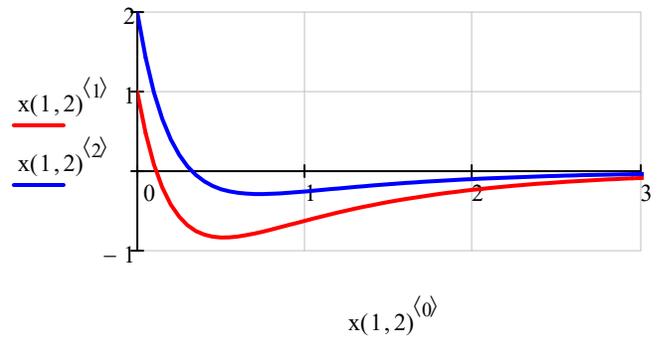
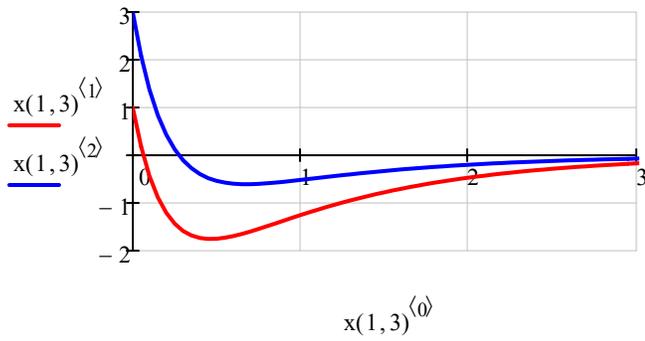
$$v1 := \frac{V(a, -3 - i \cdot 3)}{5} + 2 + 2j \quad v2 := \frac{V(a, 3 + i \cdot 3)}{5} - (2 + 2j) \quad v3 := \frac{V(a, -2.33 - i \cdot 1)}{4} + (2.341 + 1.01j)$$

$$v4 := \frac{V(a, 2.33 + i \cdot 1)}{4} - (2.341 + 1.01j)$$

$$Z := (2 + 2j \quad -2 - 2j \quad -2.33 - i \cdot 1 \quad 2.33 + i)^T$$



## Time dependance of variables (solution converges)



выбрать 2 варианта

1)  $A := \begin{pmatrix} 1 & -2 \\ -2 & -1 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -2.236 \\ 2.236 \end{pmatrix}$

2)  $A := \begin{pmatrix} 1 & -4 \\ 4 & -1 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} 3.873i \\ -3.873i \end{pmatrix}$

3)  $A := \begin{pmatrix} 1 & -4 \\ 4 & 1 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} 1 + 4i \\ 1 - 4i \end{pmatrix}$

4)  $A := \begin{pmatrix} -1 & 4 \\ -4 & -1 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -1 + 4i \\ -1 - 4i \end{pmatrix}$

5)  $A := \begin{pmatrix} 1 & 4 \\ 4 & 5 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -1.472 \\ 7.472 \end{pmatrix}$

6)  $A := \begin{pmatrix} 1 & 4 \\ 4 & -5 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -7 \\ 3 \end{pmatrix}$

7)  $A := \begin{pmatrix} -5 & 4 \\ -4 & -5 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -5 + 4i \\ -5 - 4i \end{pmatrix}$

8)  $A := \begin{pmatrix} -1 & -2 \\ -2 & -1 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -3 \\ 1 \end{pmatrix}$

- 9)  $A := \begin{pmatrix} -1 & 4 \\ -2 & 5 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} 1 \\ 3 \end{pmatrix}$
- 10)  $A := \begin{pmatrix} 1 & -4 \\ 2 & -5 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -1 \\ -3 \end{pmatrix}$
- 11)  $A := \begin{pmatrix} 2 & -8 \\ 4 & -10 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -2 \\ -6 \end{pmatrix}$
- 12)  $A := \begin{pmatrix} -2 & 1 \\ 4 & -6 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -1.172 \\ -6.828 \end{pmatrix}$
- 13)  $A := \begin{pmatrix} -4 & 2 \\ 4 & -6 \end{pmatrix}$        $\text{eigenvals}(A) = \begin{pmatrix} -2 \\ -8 \end{pmatrix}$