```
> restart;
> #Вводимо диф-ні рівняння
> d1 := diff(x(t), t) = x(t)·(e1 − g1·y(t))
```

$$d1 := \frac{d}{dt}\, x(t) = x(t)\,(3 - y(t)) \qquad (1)$$

```
> d2 := diff(y(t), t) = y(t)·(−e2 + g2·x(t))
```

$$d2 := \frac{d}{dt}\, y(t) = y(t)\,(-2 + 4\,x(t)) \qquad (2)$$

```
> # Значення змінних
> e1 := 3
```

$$e1 := 3 \qquad (3)$$

```
> g1 := 1
```

$$g1 := 1 \qquad (4)$$

```
>
> e2 := 2
```

$$e2 := 2 \qquad (5)$$

```
> g2 := 4
```

$$g2 := 4 \qquad (6)$$

```
>
> # Знаходимо стаціонарні точки
> solve({rhs(d1) = 0, rhs(d2) = 0}, {x(t), y(t)})
```

$$\{x(t) = 0, y(t) = 0\}, \left\{x(t) = \frac{1}{2}, y(t) = 3\right\} \qquad (7)$$

```
> #Розв'язуємо систему диф-них р-нь чисельними методами при
    різних початкових умовах
> dsys1 := dsolve({d1, d2, x(0) = 1, y(0) = 5}, numeric, method
    = rkf45)
```

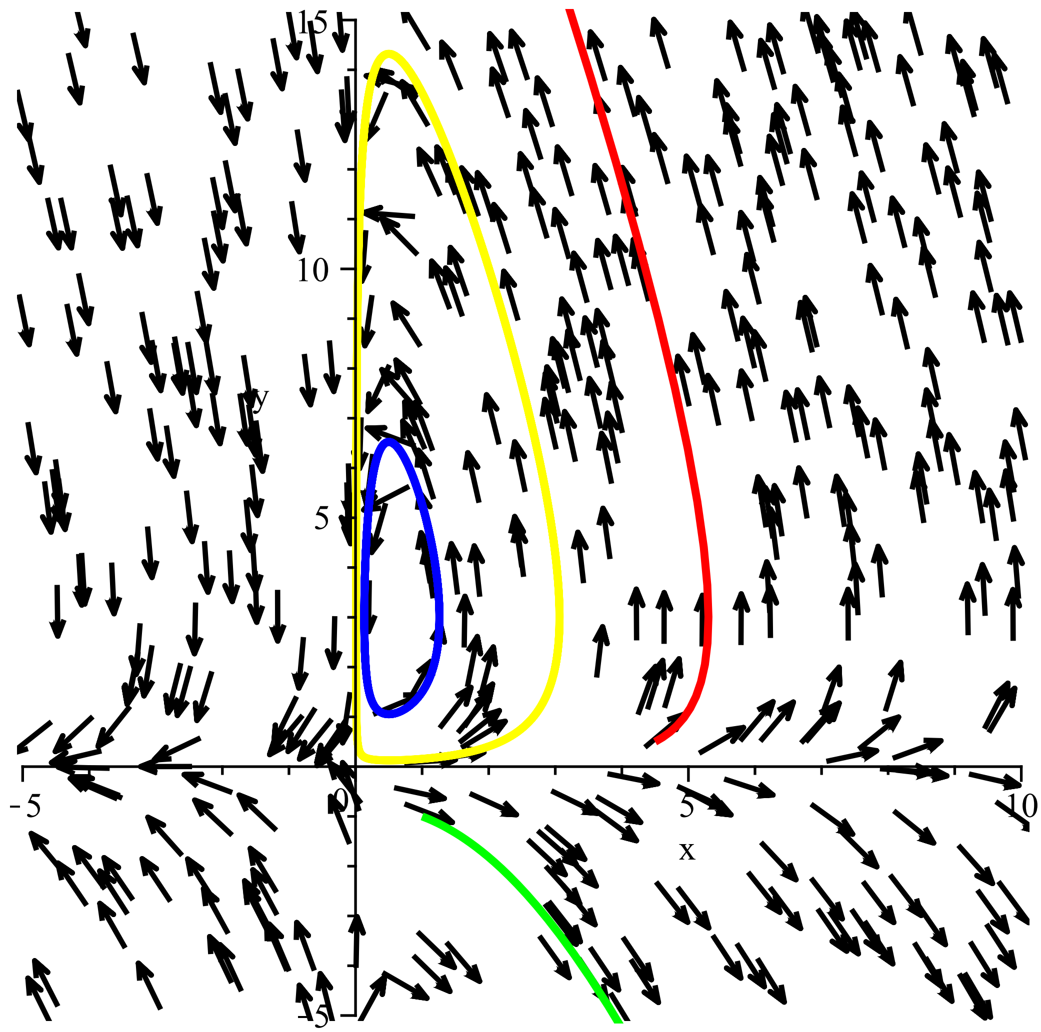
dsys1 := **proc**(*x_rkf45*) ... **end proc** (8)

```
> dsys2 := dsolve({d1, d2, x(0) = 5, y(0) = 2}, numeric, method
    = rkf45)
```

dsys2 := **proc**(*x_rkf45*) ... **end proc** (9)

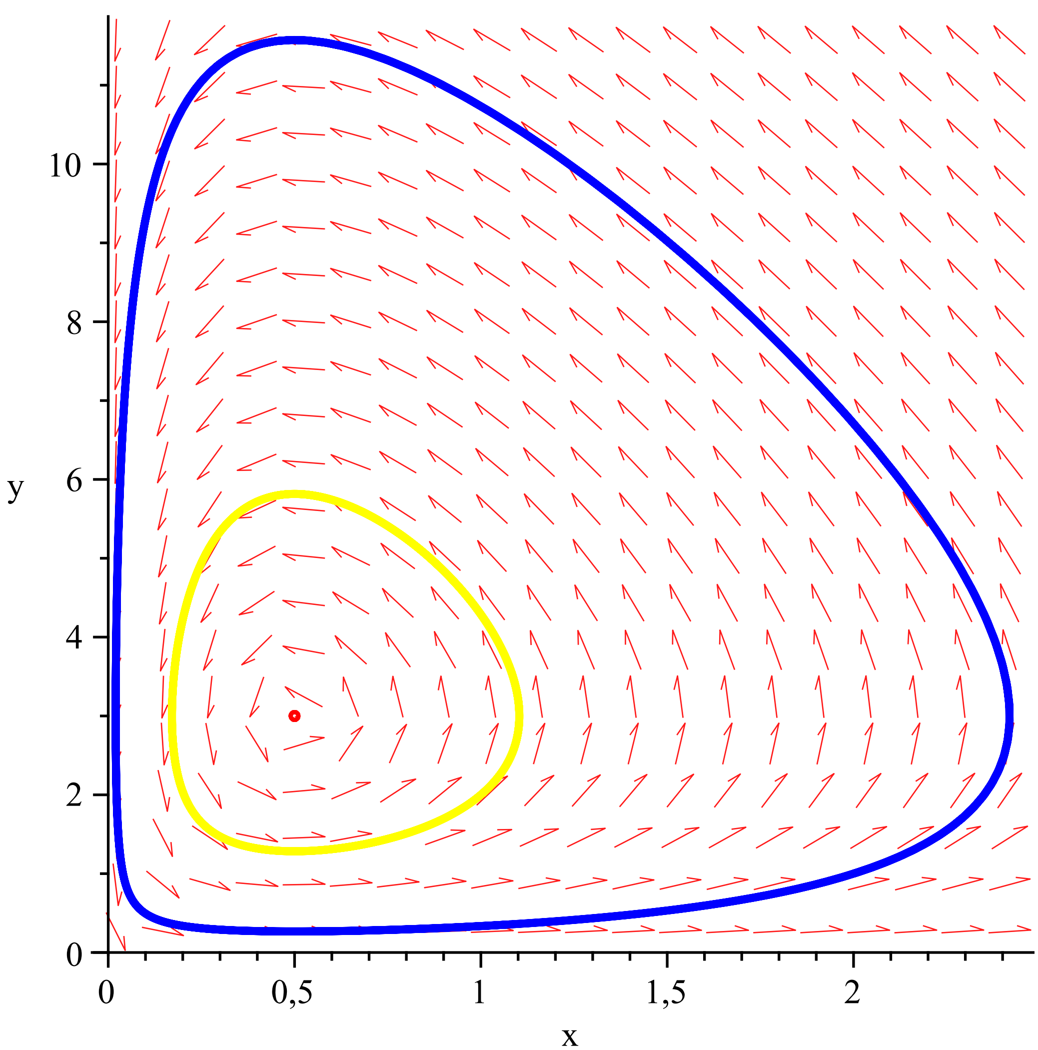
```
>
>
> with(DEtools) :
> with(plots) :
>
> #Повний фазовий портрет
```

> $DEplot([d1, d2], [x(t), y(t)], \mathrm{t} = 0..10, \mathrm{x} = -5..10, \mathrm{y} = -5..15, \mathrm{stepsize} = 0.01, [[x(0) = 1, y(0) = 1.5], [x(0) = 3, y(0) = 2], [x(0) = 1, y(0) = -1], [x(0) = 4.5, y(0) = 0.5]], \mathrm{arrows} = \mathrm{smalltwo}, \mathrm{dirfield} = 400, color = black, linecolor = [blue, yellow, green, red])$



> *# Фазовий портрет навколо стаціонарної точки 1\2 та 3 (для якої ми беремо невеликий приріст 0.005)*

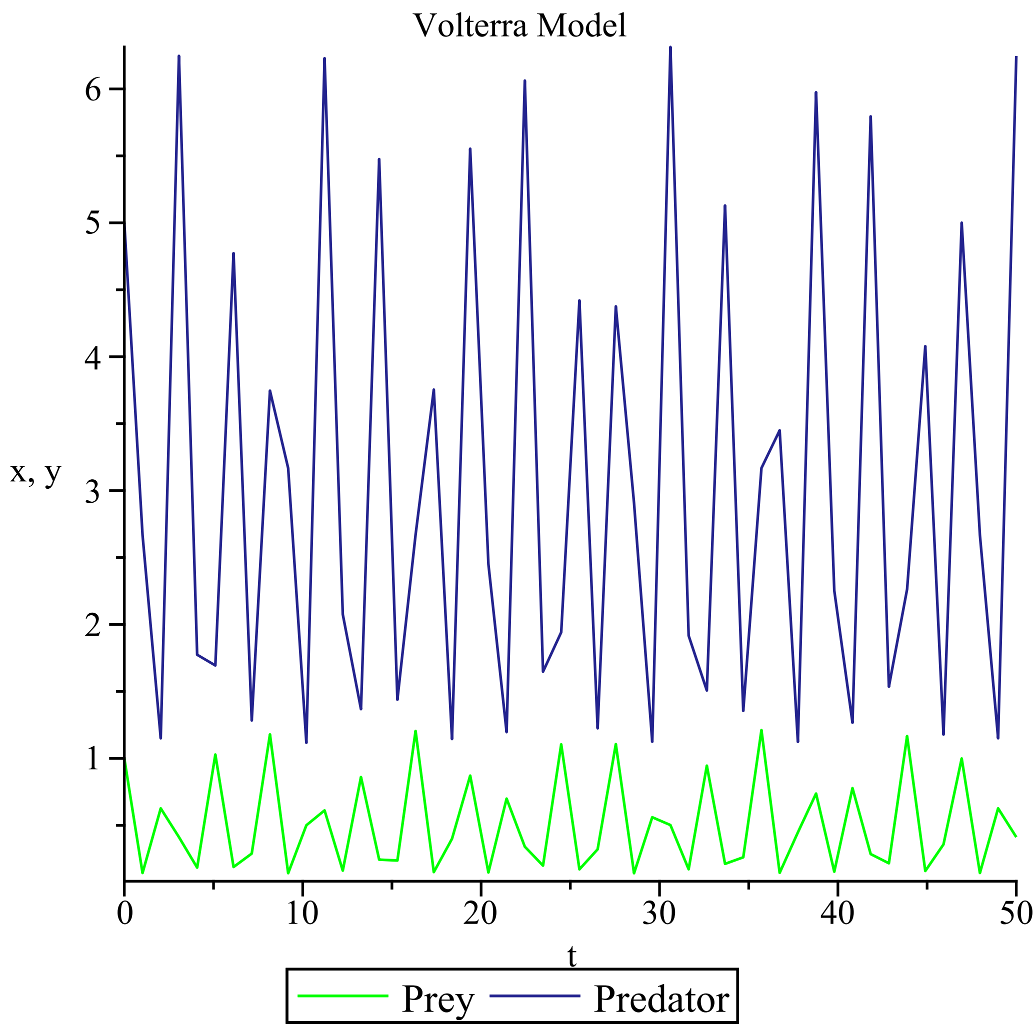
> $phaseportrait\left([d1, d2], [x(t), y(t)], t = 0 .. 10, \left[[x(0) = 1, y(0) = 2], [x(0) = 2, y(0) = 1], \left[x(0) = \frac{1}{2} + 0.005, y(0) = 3 + 0.005\right]\right], stepsize = 0.01, linecolour = [yellow, blue, red]\right)$



>

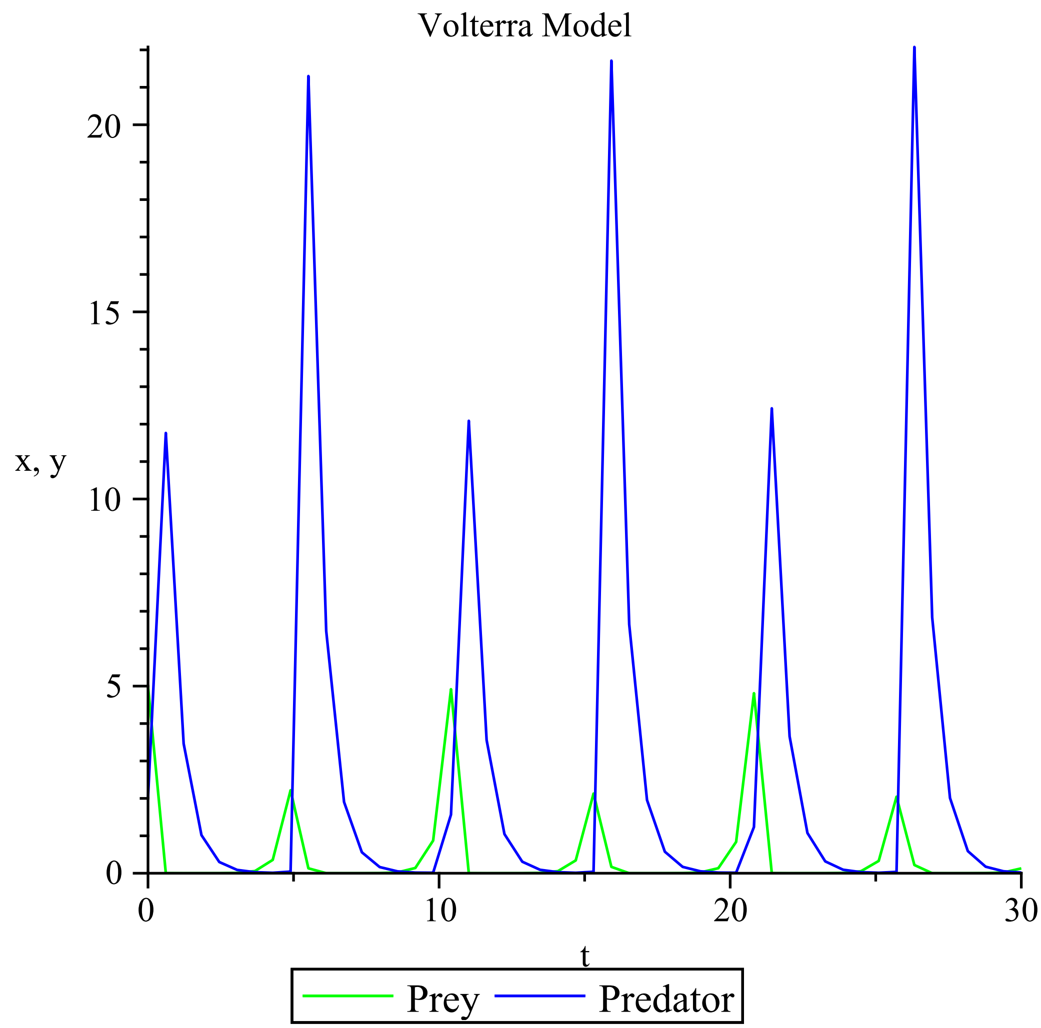
> *#Графік динаміки (при різних початкових умовах)*

> *odeplot*(*dsys1*, [[*t*, *x*(*t*), *color* = *green*], [*t*, *y*(*t*), *color* = *navy*]], *t* = 0 ..50, *title* = "Volterra Model", *legend* = ["Prey", "Predator"])

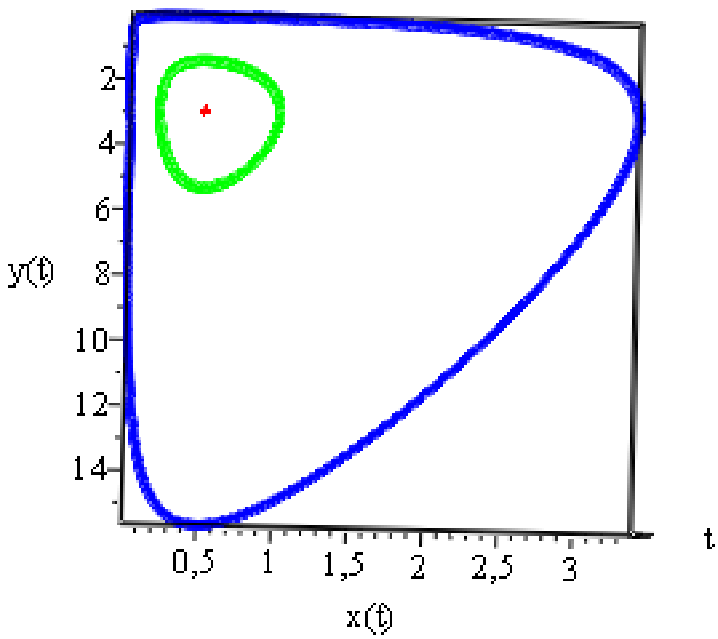


>

> $odeplot(dsys2, [[t, x(t), color = green], [t, y(t), color = blue]], t = 0..30, title = \text{"Volterra Model"}, legend = [\text{"Prey"}, \text{"Predator"}])$



> $DEplot3d\left([d1, d2], [x(t), y(t)], t = 0 .. 20, stepsize = 0.01, \left[[x(0) = 3, y(0) = 1], [x(0) = 1, y(0) = 3], \left[x(0) = \frac{1}{2}, y(0) = 3\right]\right], linecolor = [blue, green, red]\right)$



>

> *restart*;

> #Вводимо диф-ні рівняння

> $d1 := diff(x(t), t) = x(t)\cdot(e1 - g1\cdot y(t) - b1\cdot x(t))$

$$d1 := \frac{d}{dt}\, x(t) = x(t)\ (e1 - g1\ y(t) - b1\ x(t)) \tag{10}$$

> $d2 := diff(y(t), t) = y(t)\cdot(-e2 + g2\cdot x(t))$

$$d2 := \frac{d}{dt}\, y(t) = y(t)\ (-e2 + g2\ x(t)) \tag{11}$$

> # Значення змінних

> $e1 := 3$

$$e1 := 3 \tag{12}$$

> $g1 := 1$

$$g1 := 1 \tag{13}$$

> $b1 := 1$

(14)

$b1 := 1$ **(14)**

> $e2 := 2$

$e2 := 2$ **(15)**

> $g2 := 4$

$g2 := 4$ **(16)**

> *# Знаходимо стаціонарні точки*

> $solve(\{rhs(d1) = 0, rhs(d2) = 0\}, \{x(t), y(t)\})$

$$\{x(t) = 0, y(t) = 0\}, \{x(t) = 3, y(t) = 0\}, \left\{x(t) = \frac{1}{2}, y(t) = \frac{5}{2}\right\} \quad \textbf{(17)}$$

> *#Розв'язуємо систему диф-них р-нь чисельними методами при різних початкових умовах*

> $dsys1 := dsolve(\{d1, d2, x(0) = 2, y(0) = 5\}, numeric, method = rkf45)$

$dsys1 :=$ **proc**(x_rkf45) ... **end proc** **(18)**

> $dsys2 := dsolve(\{d1, d2, x(0) = 3, y(0) = 1\}, numeric, method = rkf45)$

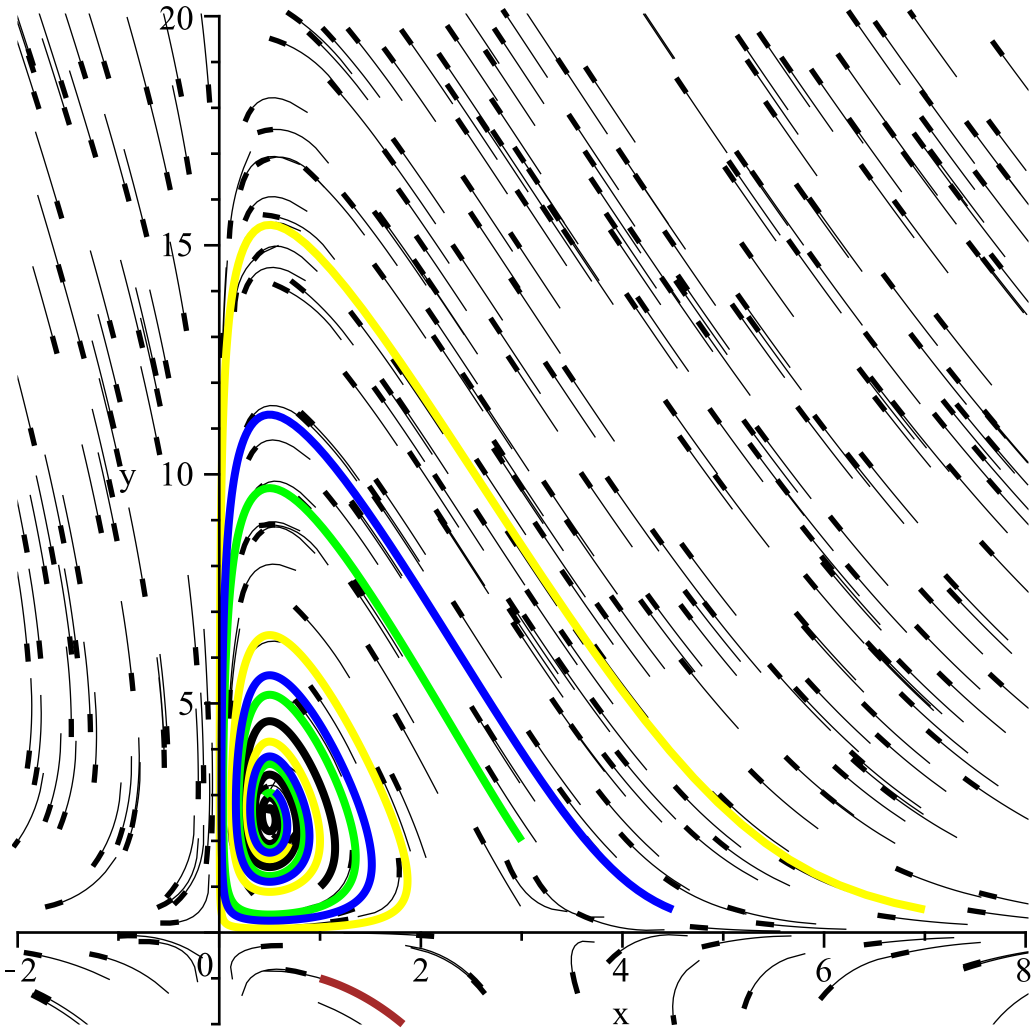
$dsys2 :=$ **proc**(x_rkf45) ... **end proc** **(19)**

> $with(DEtools):$

> $with(plots):$

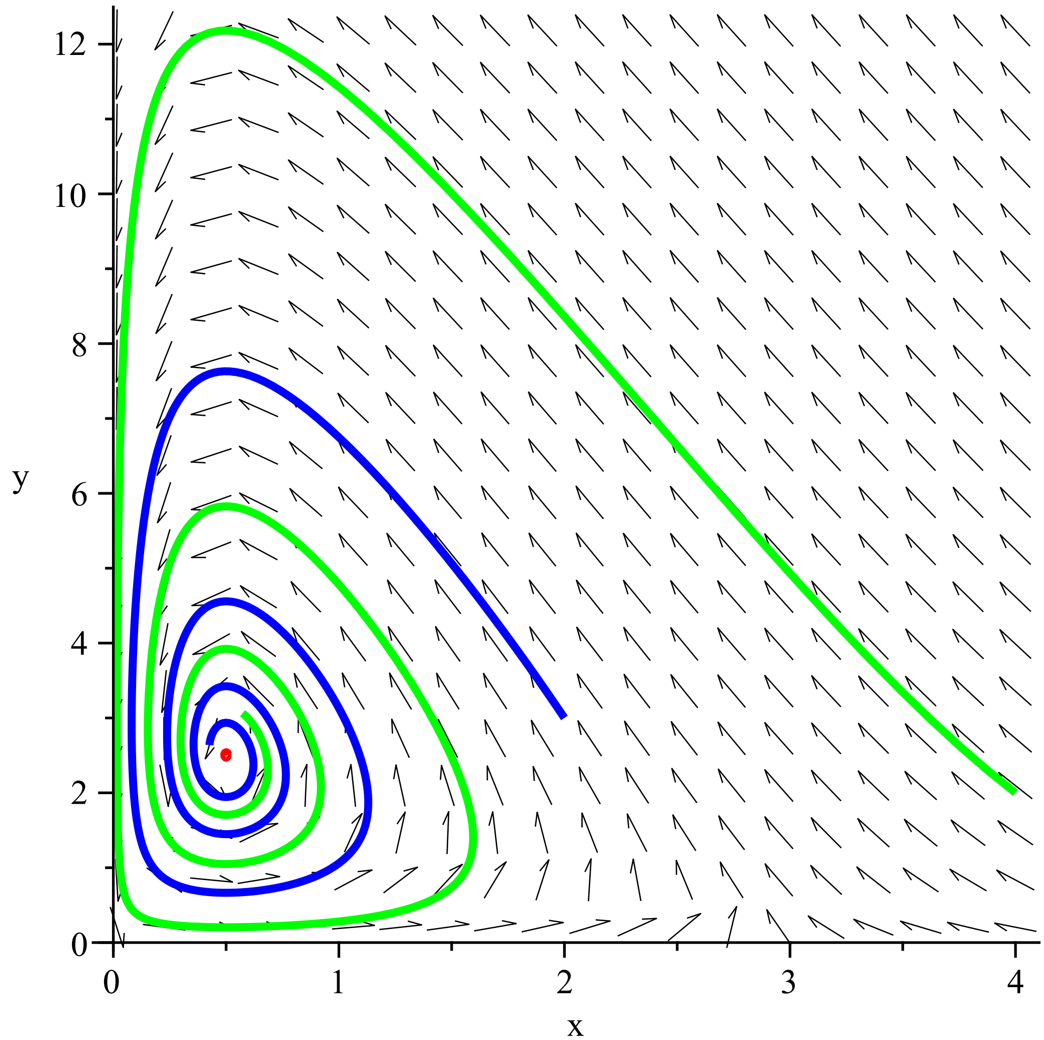
> *#Повний фазовий портрет*

> $DEplot([d1, d2], [x(t), y(t)], t = 0 ..10, x = -2 ..8, y = -2 ..20, [[x(0) = 1, y(0) = 1], [x(0) = 3, y(0) = 2], [x(0) = 1, y(0) = -1], [x(0) = 7, y(0) = 0.5], [x(0) = 4.5, y(0) = 0.5]], arrows = curve, color = black, dirfield = 400, linecolor = [black, green, brown, yellow, blue], stepsize = 0.01)$



> *#Фазовий портрет "нетривіальної" стаціонарної точки 1\2 та 5\2*

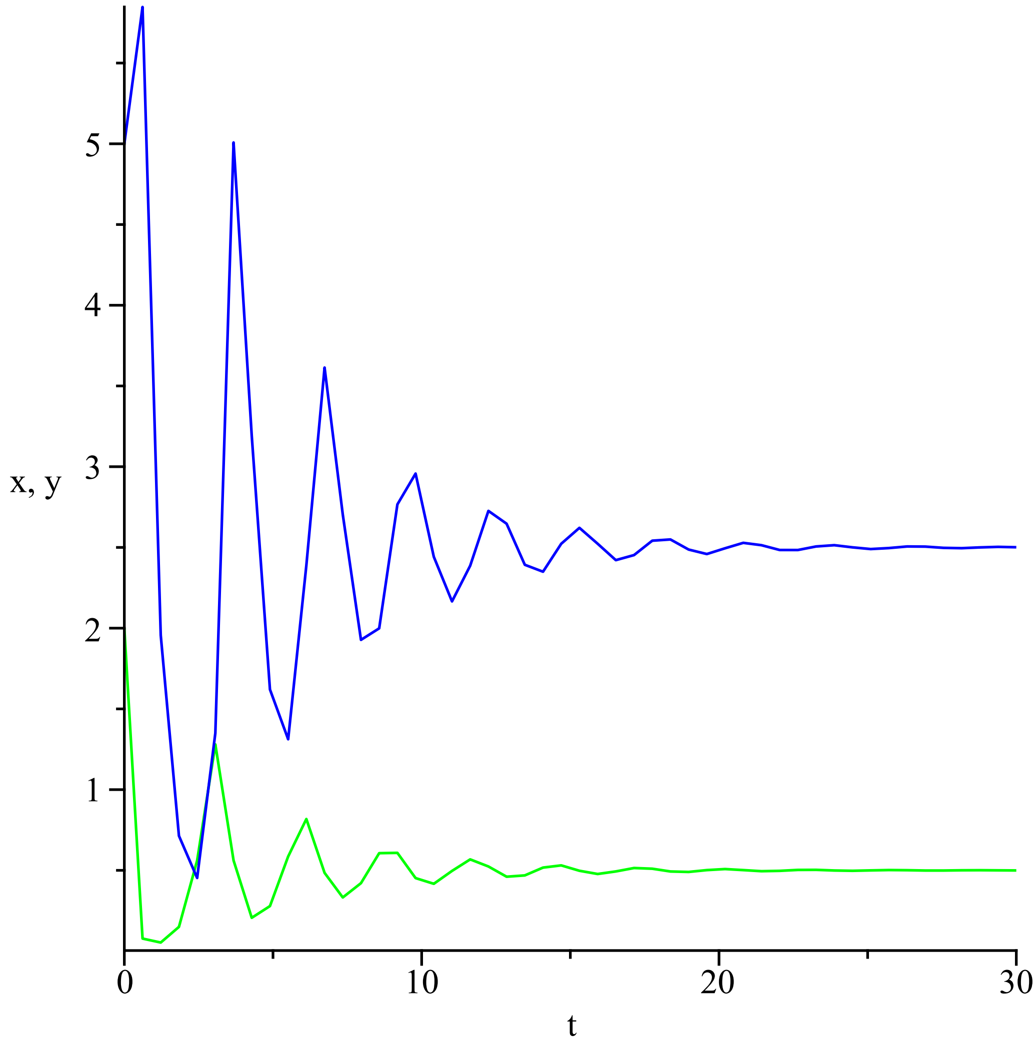
> $phaseportrait\left([d1, d2], [x(t), y(t)], t = 0 .. 10, \left[[x(0) = 2, y(0) = 3], [x(0) = 4, y(0) = 2], \left[x(0) = \frac{1}{2} + 0.01, y(0) = \frac{5}{2} + 0.01\right]\right], stepsize = 0.01, linecolour = [blue, green, red], color = black\right)$



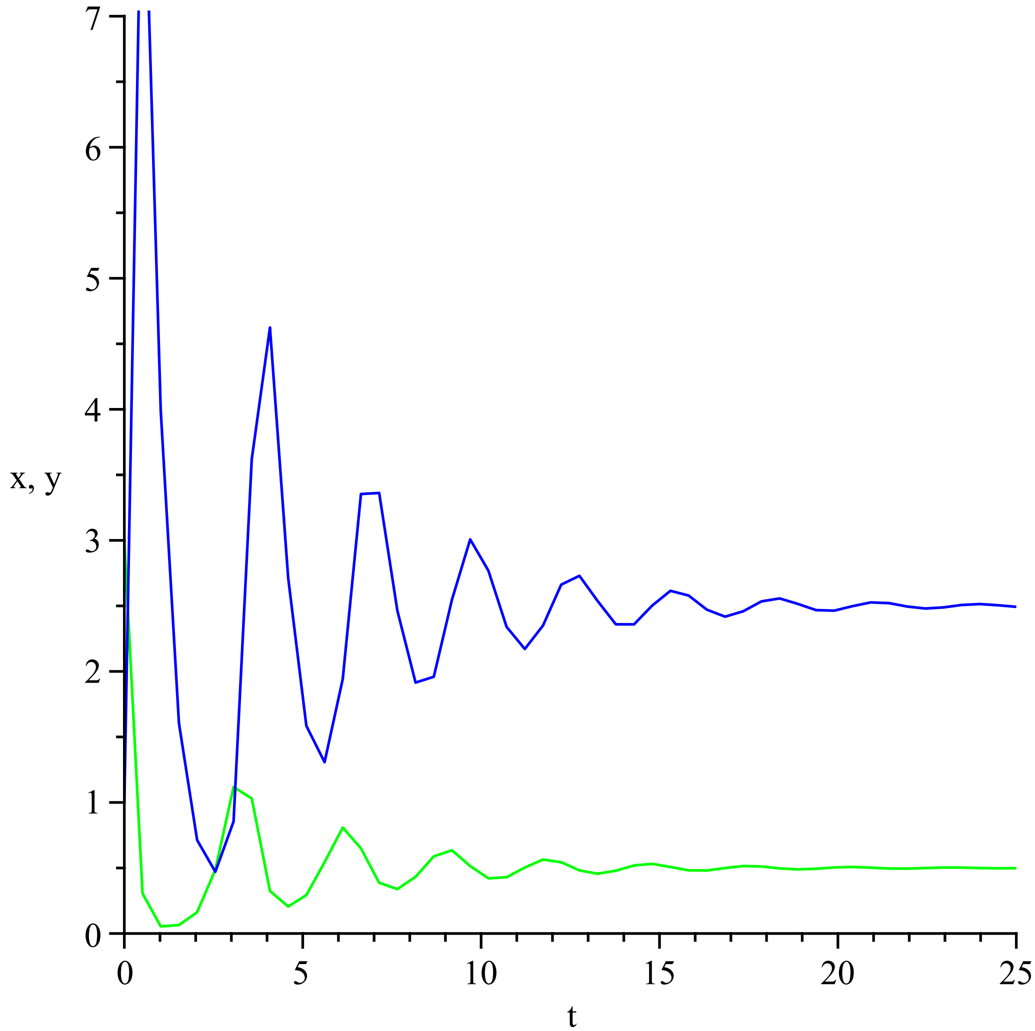
\>

\> *#Графік динаміки (при різних початкових умовах)*

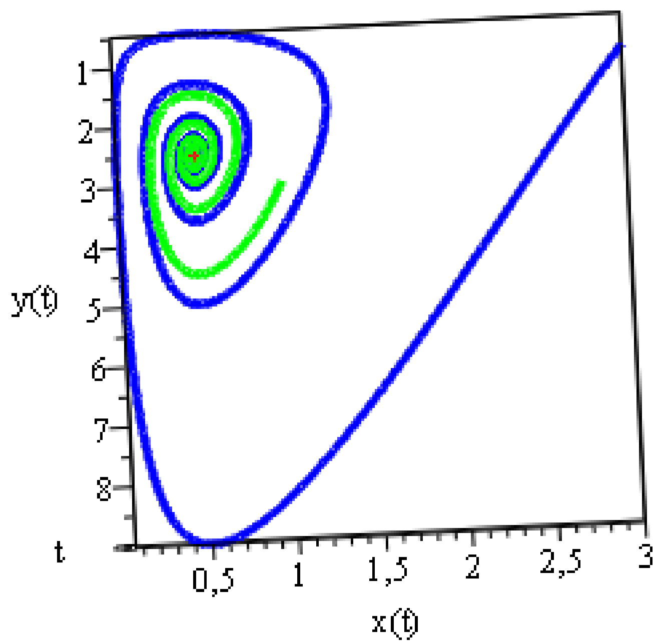
\> $odeplot(dsys1, [[t, x(t), color = green], [t, y(t), color = blue]], t = 0 ..30)$



> $odeplot(dsys2, [[t, x(t), color = green], [t, y(t), color = blue]], t = 0 ..25, view = [0 ..25, 0 ..7])$



> $DEplot3d\left(\{d1, d2\}, \{x(t), y(t)\}, t = 0 .. 25, stepsize = 0.01, \left[[x(0) = 3, y(0) = 1], [x(0) = 1, y(0) = 3], \left[x(0) = \frac{1}{2}, y(0) = \frac{5}{2}\right]\right], linecolor = [blue, green, red]\right)$



>

> *restart*;

>