> #Beginning of 2-body orbits program.

> restart;

> with(plots):

> $DEx1 := diff(x1(t), t\$2) = \frac{G \cdot m2 \cdot (x2(t) - x1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{\frac{3}{2}}};$

$$DEx1 := \frac{d^2}{dt^2}\, x1(t) = \frac{G\, m2\, (x2(t) - x1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}} \quad \textbf{(1)}$$

>

> $DEy1 := diff(y1(t), t\$2) = \frac{G \cdot m2 \cdot (y2(t) - y1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{\frac{3}{2}}}$

$$DEy1 := \frac{d^2}{dt^2}\, y1(t) = \frac{G\, m2\, (y2(t) - y1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}} \quad \textbf{(2)}$$

> $DEx2 := diff(x2(t), t\$2) = - \frac{G \cdot m1 \cdot (x2(t) - x1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{\frac{3}{2}}};$

$$DEx2 := \frac{d^2}{dt^2}\, x2(t) = - \frac{G\, m1\, (x2(t) - x1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}} \quad \textbf{(3)}$$

> $DEy2 := diff(y2(t), t\$2) = - \frac{G \cdot m1 \cdot (y2(t) - y1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{\frac{3}{2}}}$

$$DEy2 := \frac{d^2}{dt^2}\, y2(t) = - \frac{G\, m1\, (y2(t) - y1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}} \quad \textbf{(4)}$$

> $DEs := DEx1, DEy1, DEx2, DEy2;$

$$DEs := \frac{d^2}{dt^2}\, x1(t) = \frac{G\, m2\, (x2(t) - x1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}}, \frac{d^2}{dt^2}\, y1(t) = \frac{G\, m2\, (y2(t) - y1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}}, \frac{d^2}{dt^2}\, x2(t) = - \frac{G\, m1\, (x2(t) - x1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}}, \frac{d^2}{dt^2}\, y2(t) = - \frac{G\, m1\, (y2(t) - y1(t))}{\left((x1(t) - x2(t))^2 + (y1(t) - y2(t))^2\right)^{3/2}} \quad \textbf{(5)}$$

>

$$ics := x1(0) = 0, D(x1)(0) = 0, y1(0) = 0, D(y1)(0) = 0, x2(0) = 2.004600000\ 10^{11}, D(x2)(0) = 0, y2(0) = 0, D(y2)(0) = 23362 \quad \textbf{(6)}$$

>

> $G := 6.67\cdot 10^{-11};$

$$G := 6.670000000\ 10^{-11} \quad (7)$$

> $m1 := 0.96\cdot 1.989\cdot 10^{30};$

$$m1 := 1.909440000\ 10^{30} \quad (8)$$

> $m2 := 0.67\cdot 1.989\cdot 10^{30};$

$$m2 := 1.332630000\ 10^{30} \quad (9)$$

> *#std mass:*

> $mew := G\cdot m1 + G\cdot m2;$

$$mew := 2.162460690\ 10^{20} \quad (10)$$

> *#eccentricity*

> $ecc := 0.1$

$$ecc := 0.1 \quad (11)$$

> *#semimajor axis*

> $a := 0.67\cdot 1.496\cdot 10^{11}$

$$a := 1.002320000\ 10^{11} \quad (12)$$

> *#Starting distance at perihelion*

> $r := a\cdot(1 - ecc);$

$$r := 9.020880000\ 10^{10} \quad (13)$$

> *#Initial velocity*

> $vel := \mathrm{sqrt}\left(mew\cdot\left(\frac{2}{r} - \frac{1}{a}\right)\right);$

$$vel := 51350.65653 \quad (14)$$

> $ics := x1(0) = 0, \mathrm{D}(x1)(0) = 0, y1(0) = 0, \mathrm{D}(y1)(0) = 0, x2(0) = r, \mathrm{D}(x2)(0) = 0, y2(0) = 0, \mathrm{D}(y2)(0) = vel;$

$$ics := x1(0) = 0, \mathrm{D}(x1)(0) = 0, y1(0) = 0, \mathrm{D}(y1)(0) = 0, x2(0) = 9.020880000\ 10^{10}, \mathrm{D}(x2)(0) = 0, y2(0) = 0, \mathrm{D}(y2)(0) = 51350.65653 \quad (15)$$

> $solutions := dsolve(\{DEs, ics\}, numeric, output = listprocedure);$

$$solutions := \Big[t = \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc}, x1(t) = \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc}, \frac{\mathrm{d}}{\mathrm{d}t}\ x1(t) = \mathbf{proc}(t) \quad (16)$$

...

$$\mathbf{end\ proc}, x2(t) = \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc}, \frac{\mathrm{d}}{\mathrm{d}t}\ x2(t) = \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc}, y1(t) = \mathbf{proc}(t)$$

...

$$\mathbf{end\ proc}, \frac{\mathrm{d}}{\mathrm{d}t}\ y1(t) = \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc}, y2(t) = \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc}, \frac{\mathrm{d}}{\mathrm{d}t}\ y2(t) = \mathbf{proc}(t)$$

...

end proc]

> $xs1 := rhs(solutions[2]);$

$$xs1 := \textbf{proc}(t) \ \dots \ \textbf{end proc} \tag{17}$$

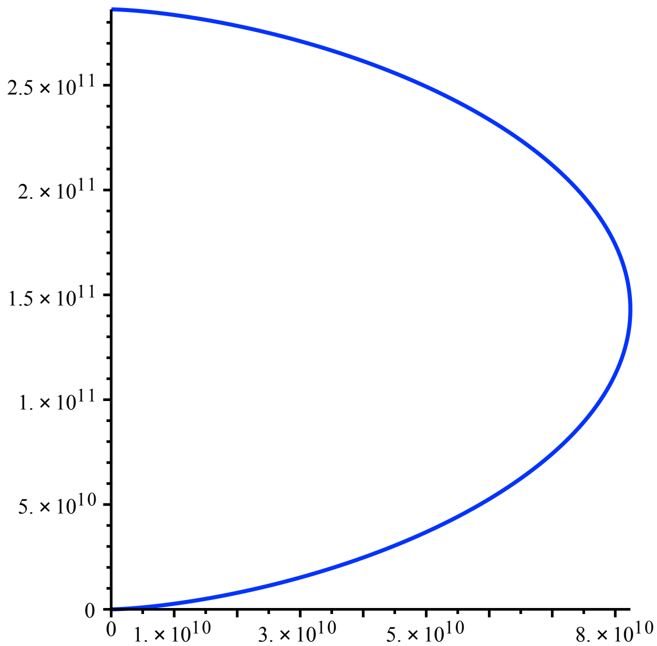
> $ys1 := rhs(solutions[6]);$

$$ys1 := \textbf{proc}(t) \ \dots \ \textbf{end proc} \tag{18}$$

> $xs1(4);$

$$0.0873831297248522 \tag{19}$$

> $plot([xs1(t), ys1(t), t = 0 ..13478400])$



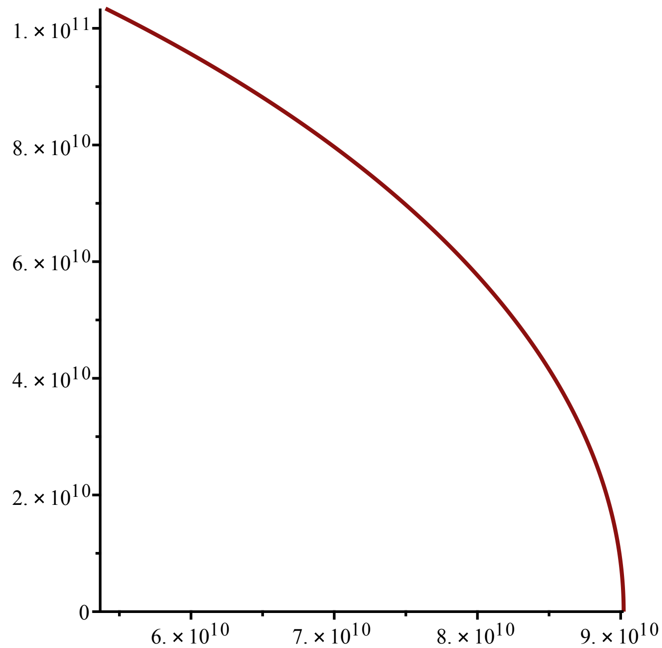
> $xs2 := rhs(solutions[4]);$

$$xs2 := \textbf{proc}(t) \ \dots \ \textbf{end proc} \tag{20}$$

> $ys2 := rhs(solutions[8]);$

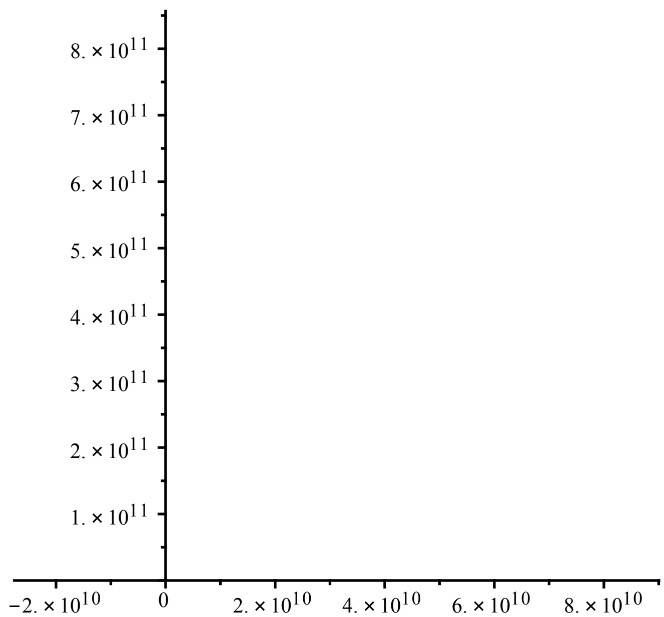
$$ys2 := \textbf{proc}(t) \ \dots \ \textbf{end proc} \tag{21}$$

> $plot([xs2(t), ys2(t), t = 0 ..2332800]);$



> $animate(plot, [[[xs1(t), ys1(t), t = 0..A], [xs2(t), ys2(t), t = 0..A]]], A = 0..3 \cdot 13478400);$

$A = 0.$



>

>

>

>

>

```
> #Beginning of the HD188753 shrinking program.
> restart;
> with(plots) :
> with(DEtools) :
```

> $DEx1 := \mathrm{diff}(x1(t), t\$2) = -\frac{G\cdot m2\cdot(x1(t)-x2(t))}{\left((x1(t)-x2(t))^2+(y1(t)-y2(t))^2\right)^{\frac{3}{2}}} - \frac{G\cdot m3\cdot(x1(t)-x3(t))}{\left((x1(t)-x3(t))^2+(y1(t)-y3(t))^2\right)^{\frac{3}{2}}}:$

> $DEx2 := \mathrm{diff}(x2(t), t\$2) = -\frac{G\cdot m3\cdot(x2(t)-x3(t))}{\left((x2(t)-x3(t))^2+(y2(t)-y3(t))^2\right)^{\frac{3}{2}}} - \frac{G\cdot m1\cdot(x2(t)-x1(t))}{\left((x2(t)-x1(t))^2+(y2(t)-y1(t))^2\right)^{\frac{3}{2}}}:$

> $DEx3 := \mathrm{diff}(x3(t), t\$2) = -\frac{G\cdot m1\cdot(x3(t)-x1(t))}{\left((x3(t)-x1(t))^2+(y3(t)-y1(t))^2\right)^{\frac{3}{2}}} - \frac{G\cdot m2\cdot(x3(t)-x2(t))}{\left((x3(t)-x2(t))^2+(y3(t)-y2(t))^2\right)^{\frac{3}{2}}}:$

> $DEy1 := \mathrm{diff}(y1(t), t\$2) = -\frac{G\cdot m2\cdot(y1(t)-y2(t))}{\left((x1(t)-x2(t))^2+(y1(t)-y2(t))^2\right)^{\frac{3}{2}}} - \frac{G\cdot m3\cdot(y1(t)-y3(t))}{\left((x1(t)-x3(t))^2+(y1(t)-y3(t))^2\right)^{\frac{3}{2}}}:$

> $DEy2 := \mathrm{diff}(y2(t), t\$2) = -\frac{G\cdot m3\cdot(y2(t)-y3(t))}{\left((x2(t)-x3(t))^2+(y2(t)-y3(t))^2\right)^{\frac{3}{2}}} - \frac{G\cdot m1\cdot(y2(t)-y1(t))}{\left((x2(t)-x1(t))^2+(y2(t)-y1(t))^2\right)^{\frac{3}{2}}}:$

> $DEy3 := \mathrm{diff}(y3(t), t\$2) = -\frac{G\cdot m1\cdot(y3(t)-y1(t))}{\left((x3(t)-x1(t))^2+(y3(t)-y1(t))^2\right)^{\frac{3}{2}}} - \frac{G\cdot m2\cdot(y3(t)-y2(t))}{\left((x3(t)-x2(t))^2+(y3(t)-y2(t))^2\right)^{\frac{3}{2}}}:$

> $G := 6.67\cdot 10^{-11};$

$$G := 6.670000000\ 10^{-11} \tag{1}$$

> #Star A

> $m1 := 1.06 \cdot 1.989 \cdot 10^{30};$

$$m1 := 2.108340000\ 10^{30} \tag{2}$$

> #Star B

> $m2 := 0.96 \cdot 1.989 \cdot 10^{30};$

$$m2 := 1.909440000\ 10^{30} \tag{3}$$

> #Star C

> $m3 := 0.67 \cdot 1.989 \cdot 10^{30};$

$$m3 := 1.332630000\ 10^{30} \tag{4}$$

> #eccentricity of outer orbit:

> $ecco := 0.5;$

$$ecco := 0.5 \tag{5}$$

> #outer orbit semi-major axis: <- This is the parameter that we shrink

> $ao := 11.8 \cdot 1.496 \cdot 10^{11};$

$$ao := 1.765280000\ 10^{12} \tag{6}$$

> #initial radius of outer orbit

> $ro := ao \cdot (1 - ecco);$

$$ro := 8.826400000\ 10^{11} \tag{7}$$

> #std gravitational parameter outer

> $mewo := G \cdot (m1 + m2 + m3);$

$$mewo := 3.568723470\ 10^{20} \tag{8}$$

> #initial outer velocity

> $velo := \mathrm{sqrt}\left(mewo \cdot \left(\frac{2}{ro} - \frac{1}{ao}\right)\right);$

$$velo := 24626.92997 \tag{9}$$

> #eccentricity of inner orbit

> $ecci := 0.1;$

$$ecci := 0.1 \tag{10}$$

> #inner orbit semi-major axis

> $ai := 0.67 \cdot 1.496 \cdot 10^{11};$

$$ai := 1.002320000\ 10^{11} \tag{11}$$

> #initial inner radius

> $ri := ai \cdot (1 - ecci);$

$$ri := 9.020880000\ 10^{10} \tag{12}$$

> #std gravitational parameter inner

> $mewi := G \cdot (m2 + m3);$

$$mewi := 2.162460690\ 10^{20} \tag{13}$$

> #initial inner velocity

> $veli := \mathrm{sqrt}\left(mewi\cdot\left(\frac{2}{ri}-\frac{1}{ai}\right)\right);$

$$veli := 51350.65653 \tag{14}$$

> #one year

> $T := 365.25\cdot 24\cdot 3600;$

$$T := 3.155760000\ 10^{7} \tag{15}$$

>

>

> $DEs := DEx1, DEy1, DEx2, DEy2, DEx3, DEy3 :$

> $ics := x1(0)=0, \mathrm{D}(x1)(0)=0, y1(0)=0, \mathrm{D}(y1)(0)=0, x2(0)=ro-ri, \mathrm{D}(x2)(0)=0, y2(0)=0, \mathrm{D}(y2)(0)=velo-\frac{veli}{1+\frac{m3}{m2}}, x3(0)=ro, \mathrm{D}(x3)(0)=0, y3(0)=0, \mathrm{D}(y3)(0)=velo+\frac{veli}{1+\frac{m2}{m3}};$

$$ics := x1(0)=0, \mathrm{D}(x1)(0)=0, y1(0)=0, \mathrm{D}(y1)(0)=0, x2(0)=7.924312000\ 10^{11}, \mathrm{D}(x2)(0)=0, y2(0)=0, \mathrm{D}(y2)(0)=-5616.40148, x3(0)=8.826400000\ 10^{11}, \mathrm{D}(x3)(0)=0, y3(0)=0, \mathrm{D}(y3)(0)=45734.25505 \tag{16}$$

> $solutions := dsolve(\{DEs, ics\}, numeric, output=listprocedure);$

$solutions := \Big[t=$ **proc**(t) ... **end proc**, $x1(t)=$ **proc**(t) ... **end proc**, $\frac{\mathrm{d}}{\mathrm{d}t}\, x1(t)=$ **proc**(t) (17)

...

end proc, $x2(t)=$ **proc**(t) ... **end proc**, $\frac{\mathrm{d}}{\mathrm{d}t}\, x2(t)=$ **proc**(t) ... **end proc**, $x3(t)=$ **proc**(t)

...

end proc, $\frac{\mathrm{d}}{\mathrm{d}t}\, x3(t)=$ **proc**(t) ... **end proc**, $y1(t)=$ **proc**(t) ... **end proc**, $\frac{\mathrm{d}}{\mathrm{d}t}\, y1(t)=$ **proc**(t)

...

end proc, $y2(t)=$ **proc**(t) ... **end proc**, $\frac{\mathrm{d}}{\mathrm{d}t}\, y2(t)=$ **proc**(t) ... **end proc**, $y3(t)=$ **proc**(t)

...

end proc, $\frac{\mathrm{d}}{\mathrm{d}t}\, y3(t)=$ **proc**(t) ... **end proc**$\Big]$

> $xs1 := rhs(solutions[2]);$

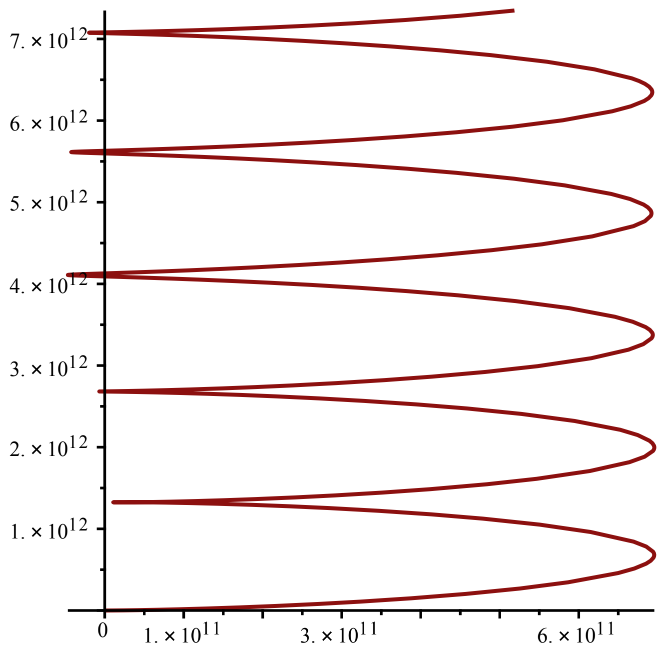
(18)

$$xs1 := \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc} \tag{18}$$

> $ys1 := rhs(solutions[8]);$

$$ys1 := \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc} \tag{19}$$

> $plot([xs1(t), ys1(t), t = 0..811030320]);$



> $xs2 := rhs(solutions[4]);$

$$xs2 := \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc} \tag{20}$$

> $ys2 := rhs(solutions[10]);$

$$ys2 := \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc} \tag{21}$$

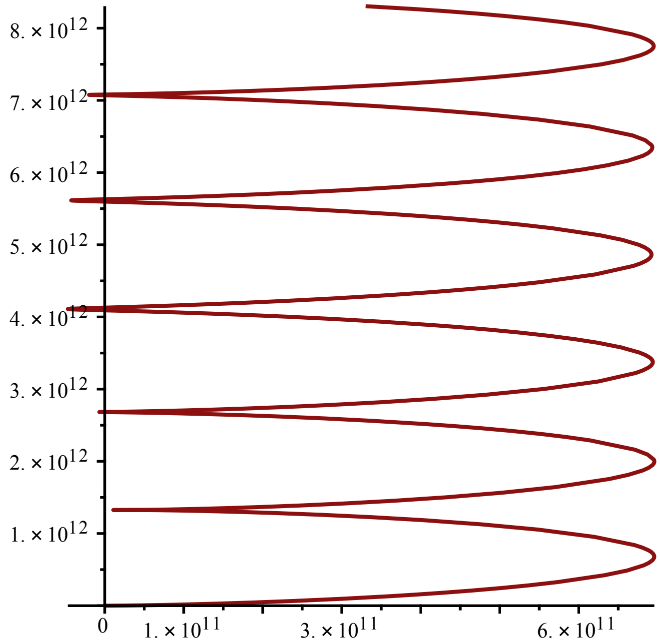
> $xs3 := rhs(solutions[6]);$

$$xs3 := \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc} \tag{22}$$

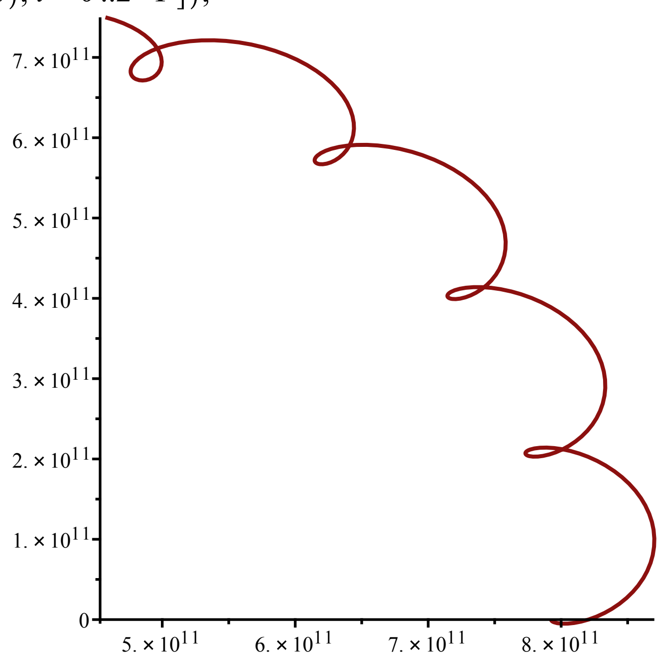
> $ys3 := rhs(solutions[12]);$

$$ys3 := \mathbf{proc}(t)\ \ldots\ \mathbf{end\ proc} \tag{23}$$

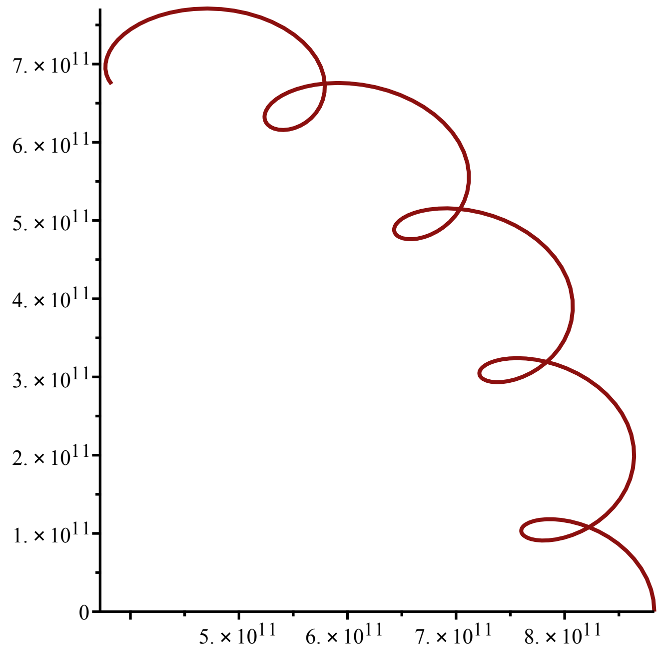
> $plot([xs1(t), ys1(t), t = 0..27 \cdot T]);$



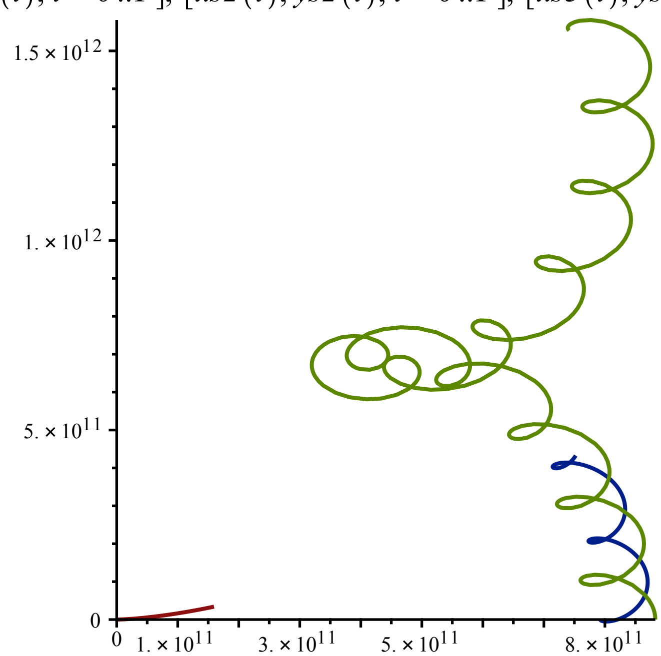
> $plot([xs2(t), ys2(t), t = 0..2 \cdot T]);$



> $plot([xs3(t), ys3(t), t = 0..2 \cdot T]);$

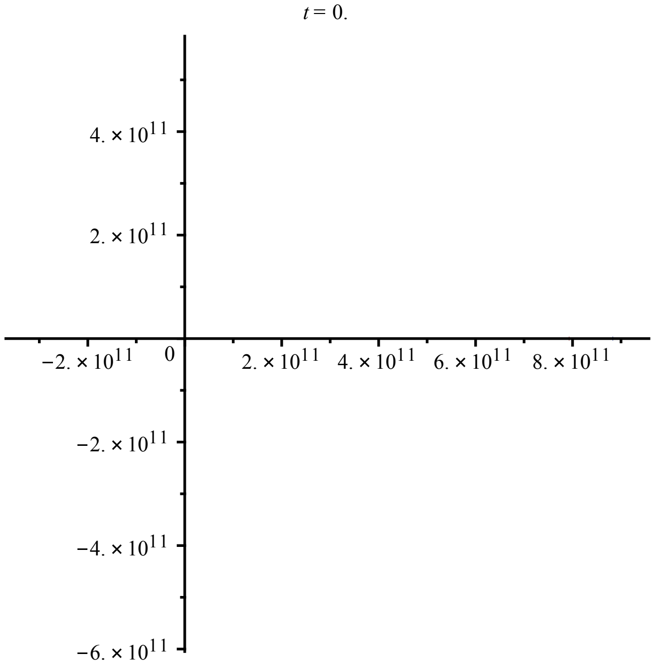


> $plot([[xs1(t), ys1(t), t = 0..T], [xs2(t), ys2(t), t = 0..T], [xs3(t), ys3(t), t = 0..5 \cdot T]])$



> *#Plot with all three bodies for 95% of an earth year*

> $\#animate(plot, [[[xs2(s \cdot T) - xs1(s \cdot T), ys2(s \cdot T) - ys1(s \cdot T), s = 0..t], [xs3(s \cdot T) - xs1(s \cdot T), ys3(s \cdot T) - ys1(s \cdot T), s = 0..t]]], t = 0..9);$



> *#Plot with just the second two systems.*

> $\#animate(plot, [[[xs2(t), ys2(t), t = 0..A], [xs3(t), ys3(t), t = 0..A]]], A = 0..20 \cdot T, frames = 50);$

>

>