Pendulum

(%i2) `info:build_info()$info@version;`

(%o2)

5.38.1

(%i2) `reset()$kill(all)$`

(%i1) `derivabbrev:true$`

(%i2) `ratprint:false$`

(%i3) `fpprintprec:5$`

(%i4) `if get('draw,'version)=false then load(draw)$`

(%i5) `wxplot_size:[1024,768]$`

(%i6) `if get('rkf45,'version)=false then load(rkf45)$`

(%i7) `declare(trigsimp,evfun)$`

(%i8) `declare(t,mainvar)$`

(%i9) `orderless(g,A,ω)$`

(%i10) `declare([g,A,ω],constant)$`

(%i11) `assume(g>0,A>0,ω>0)$`

(%i12) `params:[g=9.8,A=0.1,ω=0.1]$`

(%i13) `τ:10$`

(%i14) `DE:'diff(θ,t,2)=A*cos(θ)*ω^2*cos(t*ω)-g*sin(θ);`

$$\theta_{tt} = A\,\omega^2\,\cos\left(\theta\right)\,\cos\left(\omega t\right) - g\,\sin\left(\theta\right) \tag{DE}$$

Small angles approximation

(%i16) `Cθ:ratdisrep(taylor(cos(θ),θ,0,1))$`
`Sθ:ratdisrep(taylor(sin(θ),θ,0,1))$`

(%i17) `subst([cos(θ)=Cθ,sin(θ)=Sθ],DE);`

$$\theta_{tt} = A\,\omega^2\,\cos\left(\omega t\right) - g\theta \tag{%o17}$$

(%i18) `ode2(%,θ,t);`

$$\theta = -\frac{A\,\omega^2\,\cos\left(\omega t\right)}{\omega^2 - g} + \%k1\,\sin\left(\sqrt{g}t\right) + \%k2\,\cos\left(\sqrt{g}t\right) \tag{%o18}$$

Reduce order

(%i19)
```
depends(Θ,t)$
```

(%i20)
```
gradef(θ,t,Θ)$
```

(%i21)
```
DE:ev(DE,diff,eval);
```

$$\Theta_t = A\,\omega^2\,\cos(\theta)\,\cos(\omega t) - g\,\sin(\theta) \tag{DE}$$

(%i29)
```
funcs:[θ,Θ]$ldisplay(funcs)$
initial:[π/7,1]$ldisplay(initial)$
odes:[Θ,rhs(DE)]$ldisplay(odes)$
interval:[t,0,τ]$ldisplay(interval)$
```

$$funcs = [\theta, \Theta] \tag{\%t23}$$

$$initial = [\frac{\pi}{7}, 1] \tag{\%t25}$$

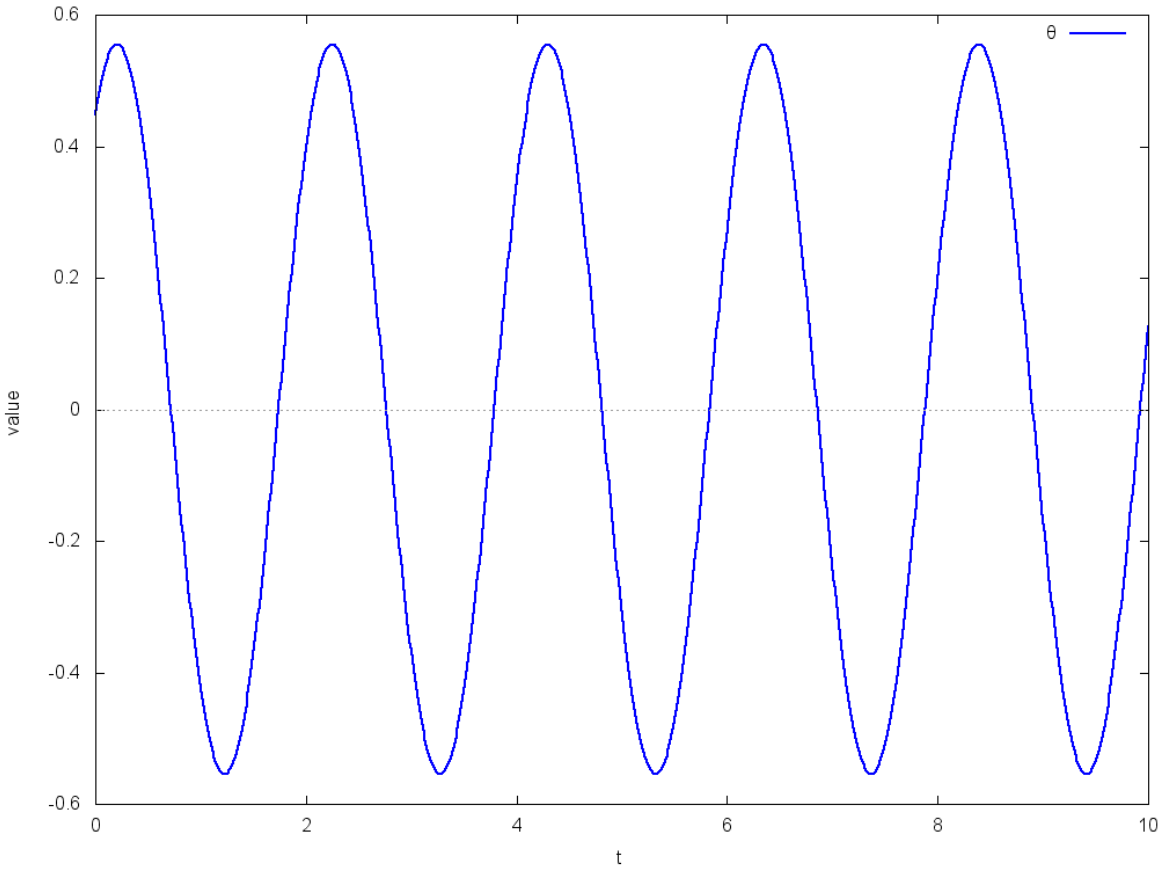
$$odes = [\Theta, A\,\omega^2\,\cos(\theta)\,\cos(\omega t) - g\,\sin(\theta)] \tag{\%t27}$$

$$interval = [t, 0, 10] \tag{\%t29}$$

(%i30)
```
rksol:rkf45(odes,funcs,initial,interval, absolute_tolerance=1E-8,report=true),params$
```

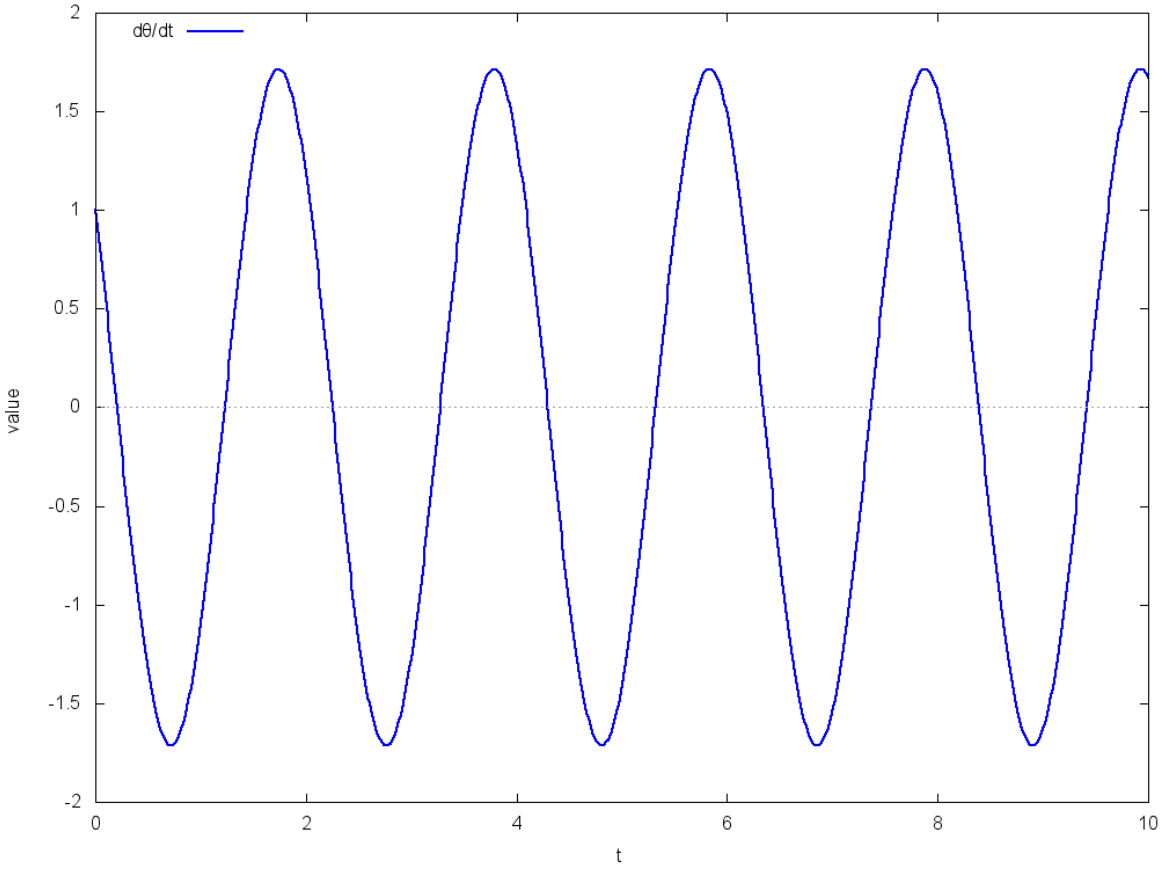
Info: rkf45:
Integration points selected:893
Total number of iterations:893
Bad steps corrected:1
Minimum estimated error:3.90510^{-9}
Maximum estimated error:5.473610^{-9}
Minimum integration step taken:0.010169
Maximum integration step taken:0.01287

(%i31) `wxplot2d([discrete,map(lambda([u],part(u,[1,2])),rksol)], [style,[lines,2]],[xlabel,"t"],[ylabel`
`[legend,"θ"],[gnuplot_preamble,"set key top right"])$`



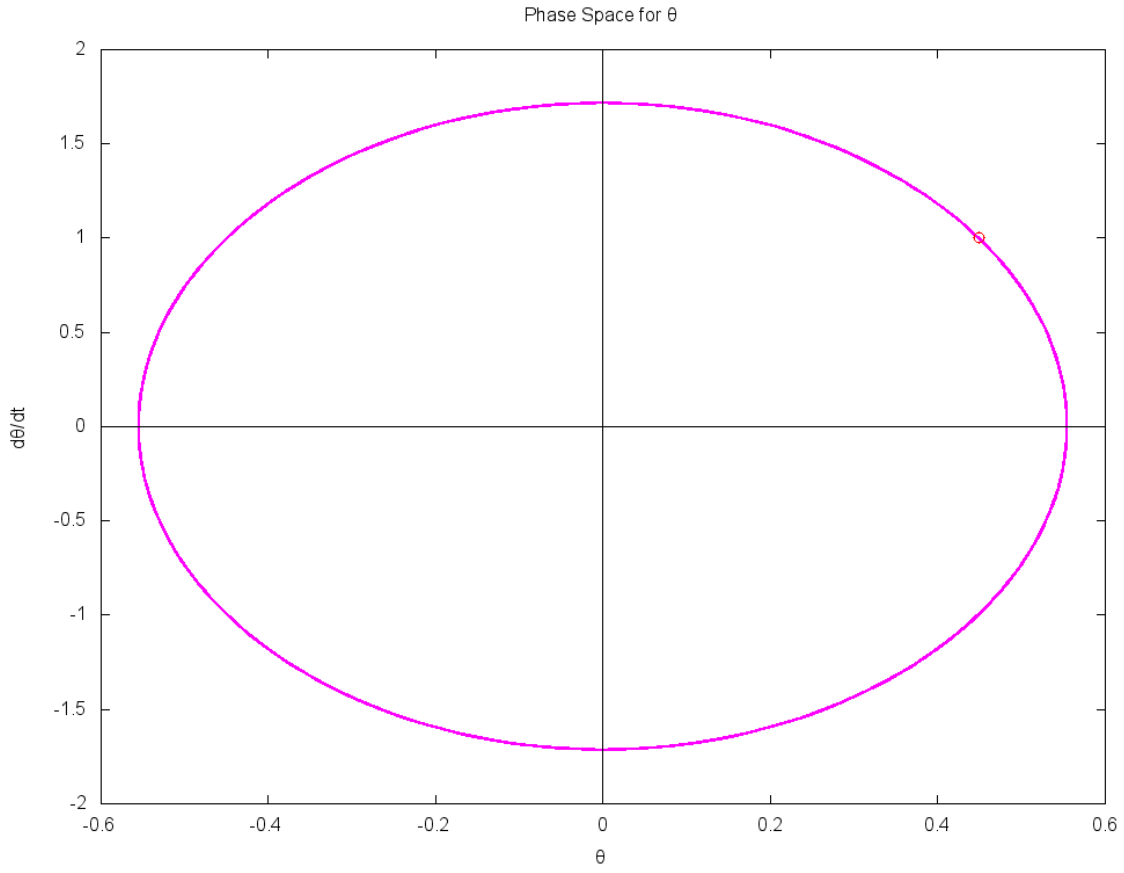
(%t31)

(%i32) wxplot2d([discrete,map(lambda([u],part(u,[1,3])),rksol)], [style,[lines,2]],[xlabel,"t"],[ylabel
[legend,"dθ/dt"],[gnuplot_preamble,"set key top left"])$



(%t32)

(%i33)
```
wxplot2d([[discrete,map(lambda([u],part(u,[2,3])),rksol)], [discrete,[part(initial,[1,2])]]],[ax
[title,"Phase Space for θ"],[point_type,circle], [style,[lines,2],[points,3]],[color,magenta,red]
[xlabel,"θ"],[ylabel,"dθ/dt"],[legend,false])$
```



(%t33)

(%i34)
```
kill(labels)$
```

(%i1)
```
wxanimate_framerate:60$
```

(%i2)
```
wxanimate_autoplay:false$
```

(%i3)
```
rksol:rk(odes,funcs,initial,[t,0,τ,0.1]),params$
```

(%i4)
```
set_draw_defaults(proportional_axes = xy, delay = 1, xtics = 1, ytics = 1, xrange =
[-1,1], yrange = [-1,0])$
```

Create animated GIF file

(%i5)
```
draw(terminal = 'animated_gif, file_name = "Pendulum", makelist(gr2d( color
= red, point_type = filled_circle, point_size = 2, points_joined = true,
line_width = 2, key = sconcat("t=",float(t)/10," s"), points([[0.0,0.0],
[sin(rksol[t][2]),-cos(rksol[t][2])]])), t,1,length(rksol))),params$
```

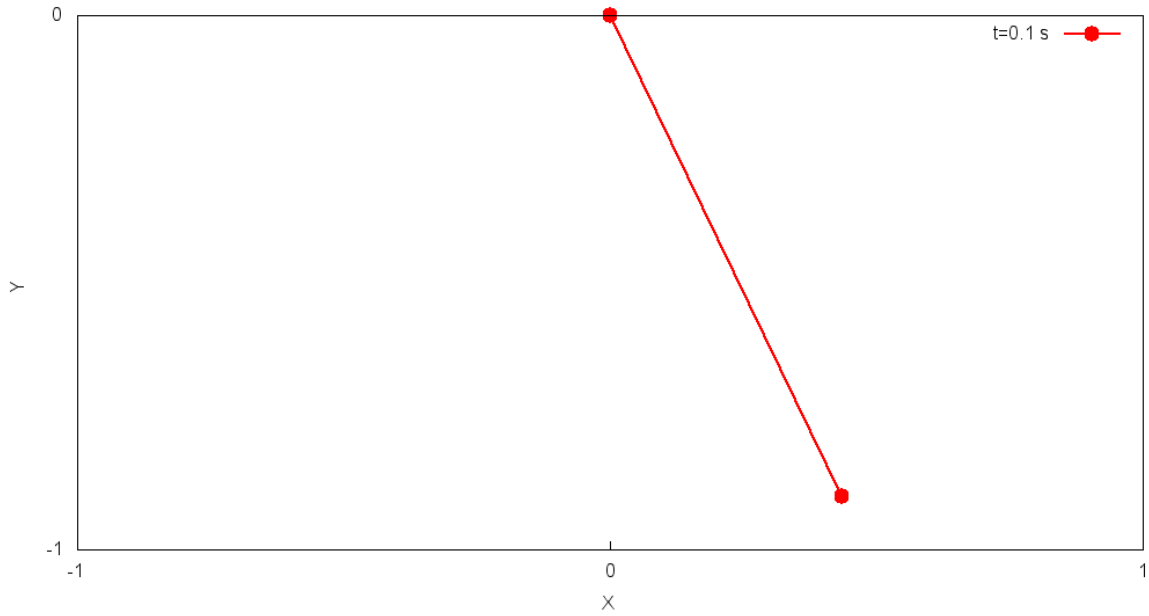
(%i6)
```
time(%);
```

[0.0] (%o6)

(%i7)
```
wxanimate_framerate:30$
```

(%i9)
```
print("Click the figure to start animation")$ with_slider_draw( t,makelist(i,i,1,length(rksol)),
color = red, point_type = filled_circle, point_size = 2, points_joined = true,
line_width = 2, key = sconcat("t=",float(t)/10," s"), points([[0.0,0.0],
[sin(rksol[t][2]),-cos(rksol[t][2])]])),params$
```

Click the figure to start animation



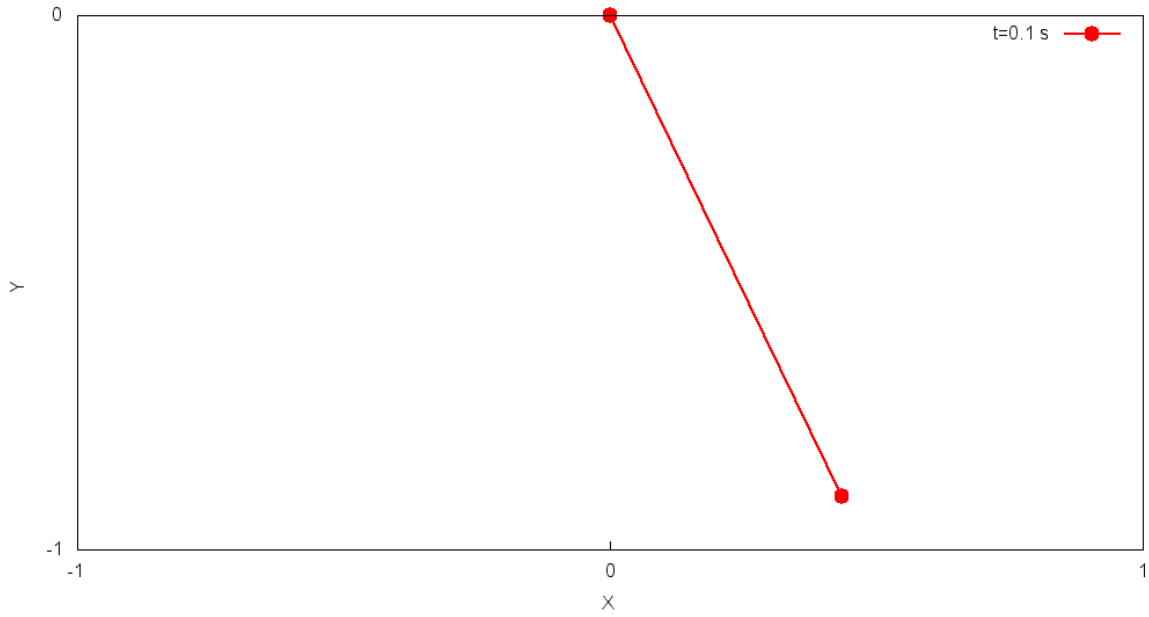
(%t9)

(%i10)
```
time(%);
```

[0.265] (%o10)

(%i12)
```
print("Click the figure to start animation")$ wxanimate_draw( t,length(rksol),
color = red, point_type = filled_circle, point_size = 2, points_joined = true,
line_width = 2, key = sconcat("t=",float(t)/10," s"), points([[0.0,0.0],
[sin(rksol[t][2]),-cos(rksol[t][2])]])),params$
```

Click the figure to start animation



(%t12)

(%i13)
```
time(%);
```

[0.203] (%o13)