2019-10-08
Although I just adore four, we have to jive with five.

Phugoid continues.

$$\frac{d}{dt}\theta(t) = v(t) - \frac{\cos(\theta(t))}{v(t)} \qquad \frac{d}{dt}v(t) = -\sin(\theta(t)) - R\cdot v(t)^2$$

> $with(DEtools):$

> $\# \; D \; is \; the \; differential \; operator$
$\mathrm{D}(\sin)$

$$\cos \tag{1}$$

> $$phug := \left[\mathrm{D}(\mathrm{theta})(t) = v(t) - \frac{\cos(\mathrm{theta}(t))}{v(t)}, \mathrm{D}(v)(t) = -\sin(\mathrm{theta}(t)) - R \cdot v(t)^2\right]:$$

> $R := 0;$

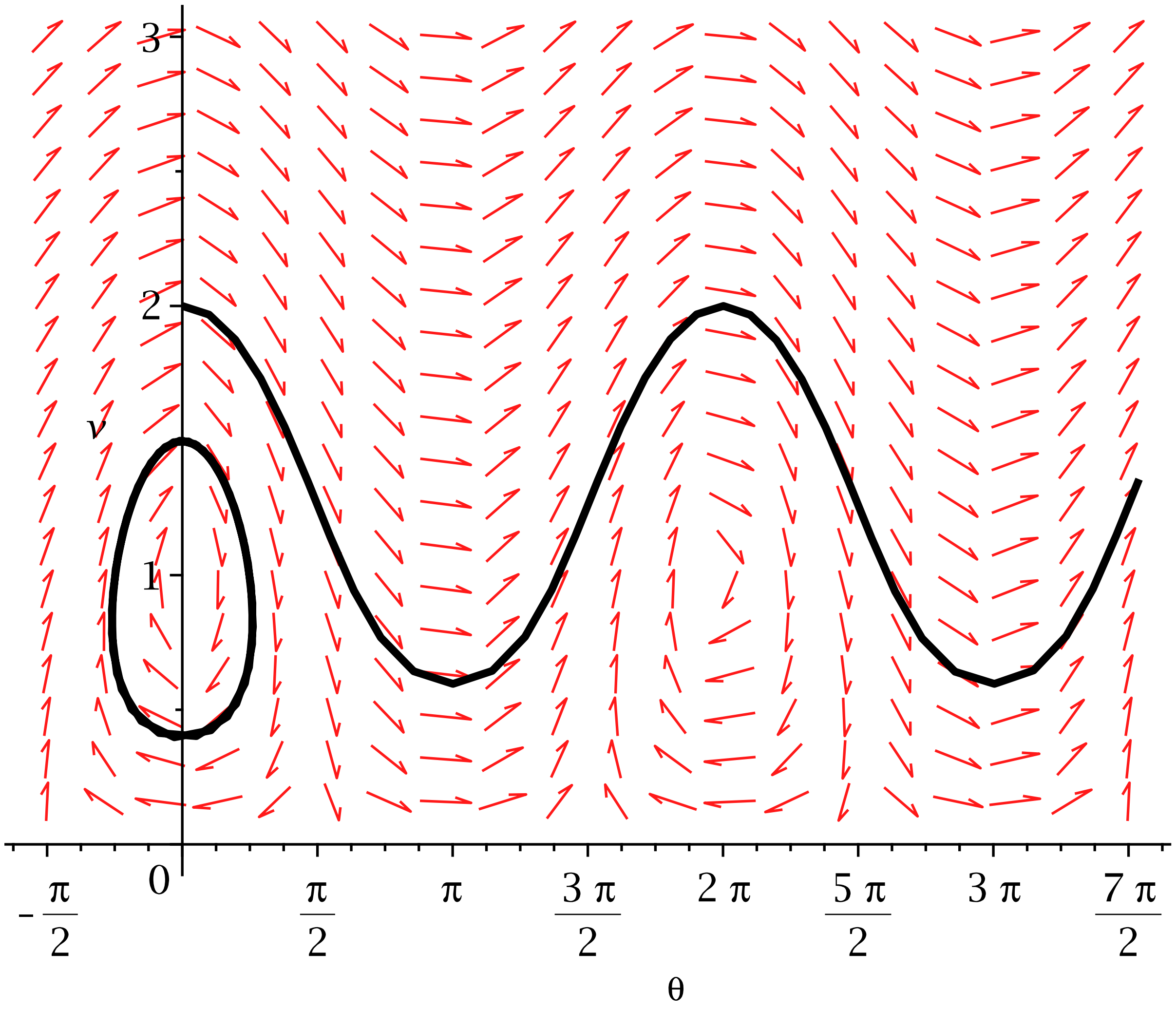
$$DEplot\Big( phug, [\mathrm{theta}(t), v(t)], t = 0..10,$$

$$[[\mathrm{theta}(0) = 0, v(0) = 1.5], [\mathrm{theta}(0) = 0, v(0) = 2]],$$

$$\# \; these \; are \; my \; initial \; values...$$

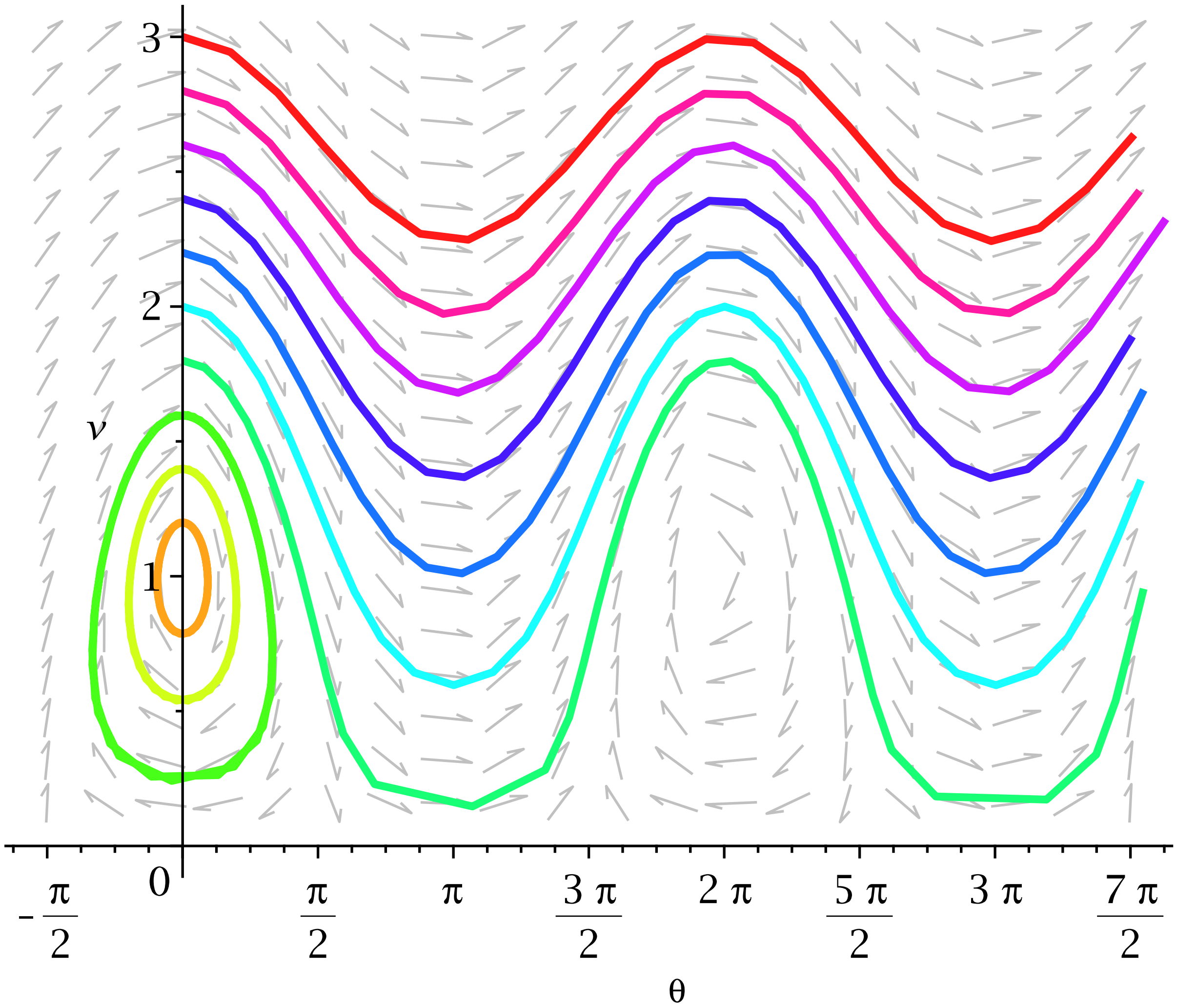
$$\mathrm{theta} = -\frac{\mathrm{Pi}}{2}..\frac{7\,\mathrm{Pi}}{2}, v = 0..3, tickmarks = [piticks, default], linecolor = black\Big)$$

$$R := 0$$



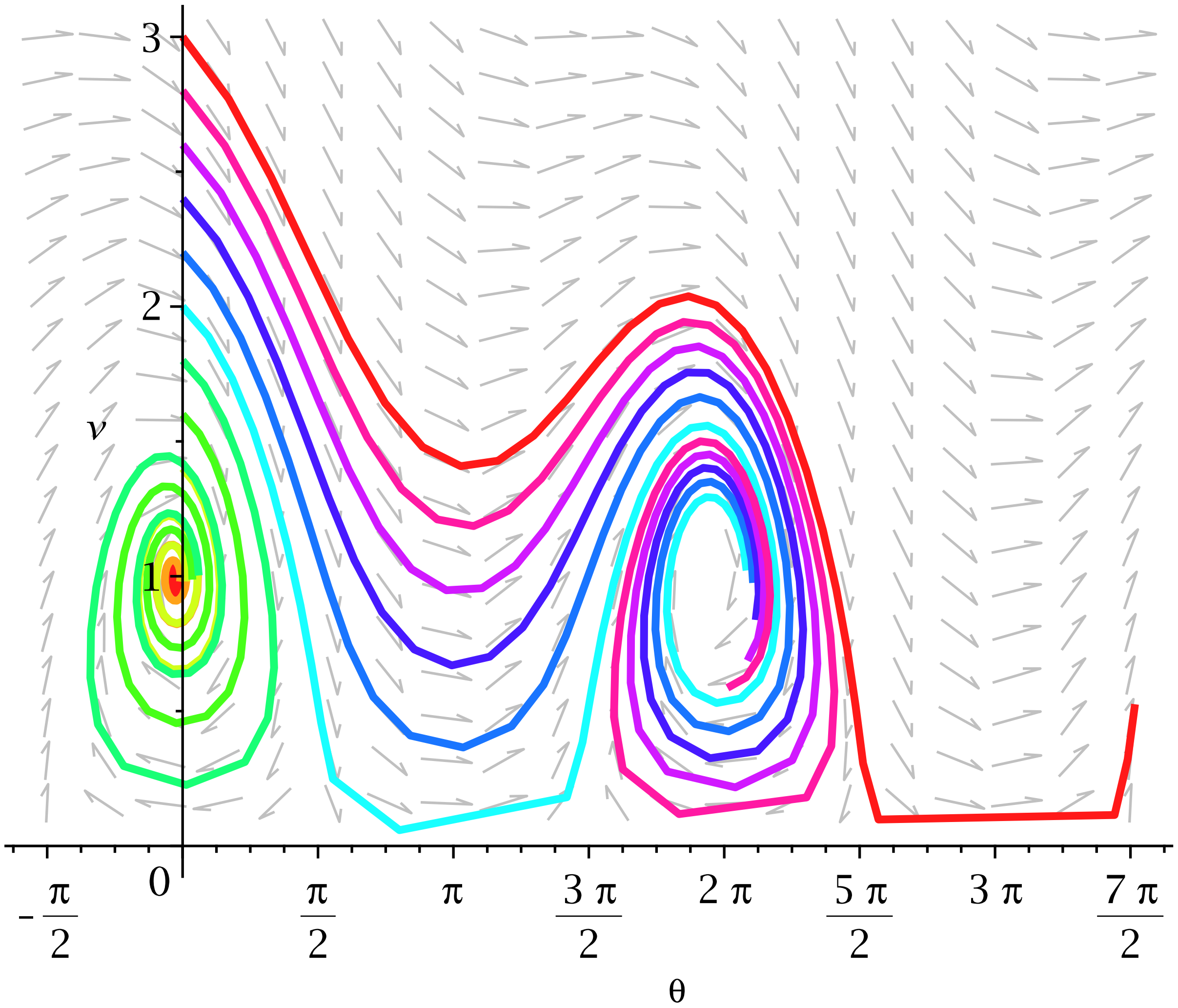
```
> R := 0;
  DEplot( phug, [theta(t), v(t)], t = 0 ..10,
     [seq([theta(0) = 0, v(0) = initv],  initv = 1 ..3, .2) ],
      # these are my initial values...
     theta = - Pi/2 .. 7 Pi/2, v = 0 ..3, tickmarks = [piticks, default],
     linecolor = [seq(COLOR(HUE, hval), hval = 0 ..1, 0.1) ], color = gray)
      # color of arrows is gray
```

R := 0

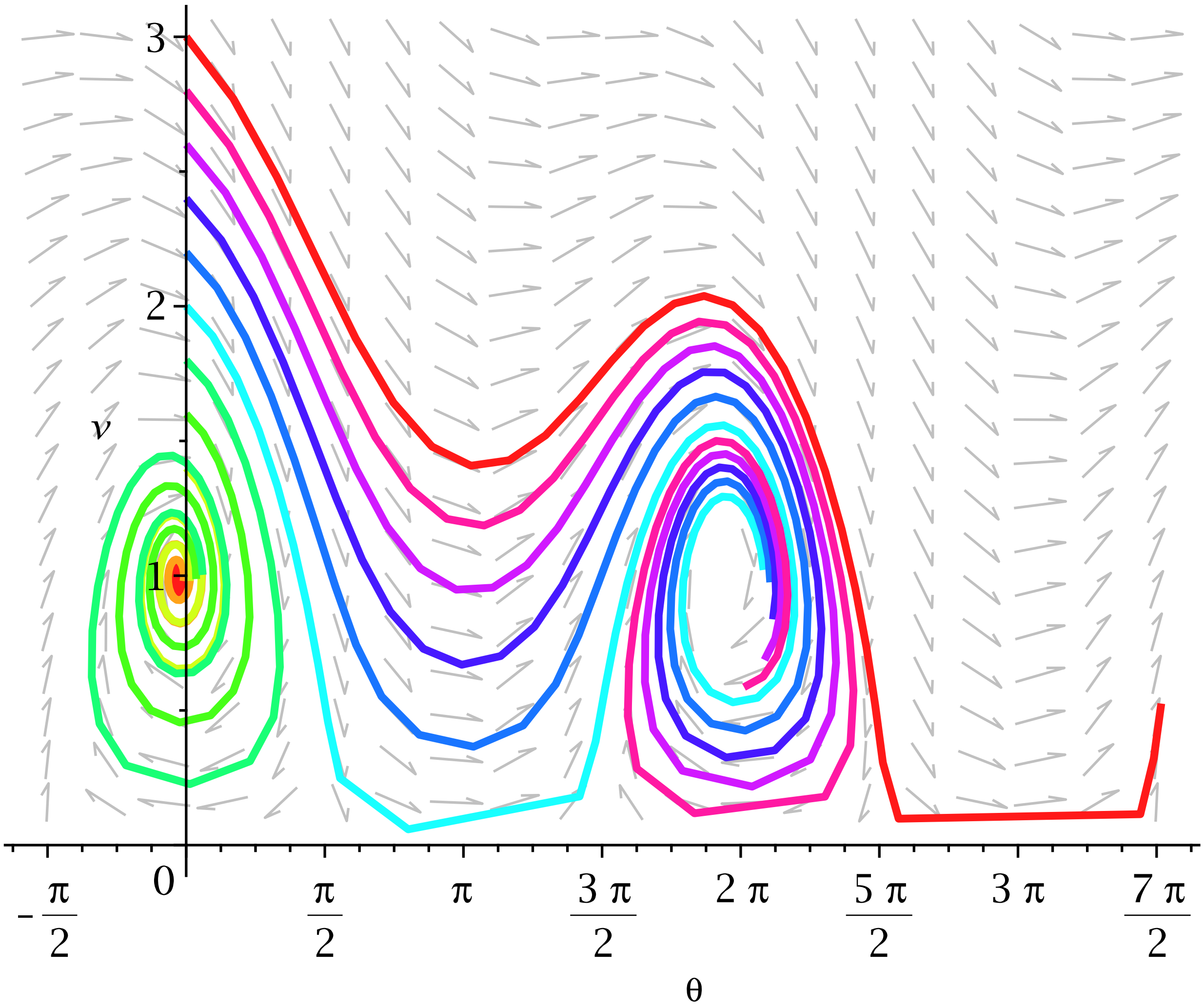


```
> R := 0.1;
  DEplot( phug, [theta(t), v(t)], t = 0..10,
     [seq([theta(0) = 0, v(0) = initv], initv = 1..3, .2)],
      # these are my initial values...
     theta = -Pi/2 .. 7 Pi/2, v = 0..3, tickmarks = [piticks, default],
     linecolor = [seq(COLOR(HUE, hval), hval = 0..1, 0.1)], color = gray)
      # color of arrows is gray
```

$$R := 0.1$$

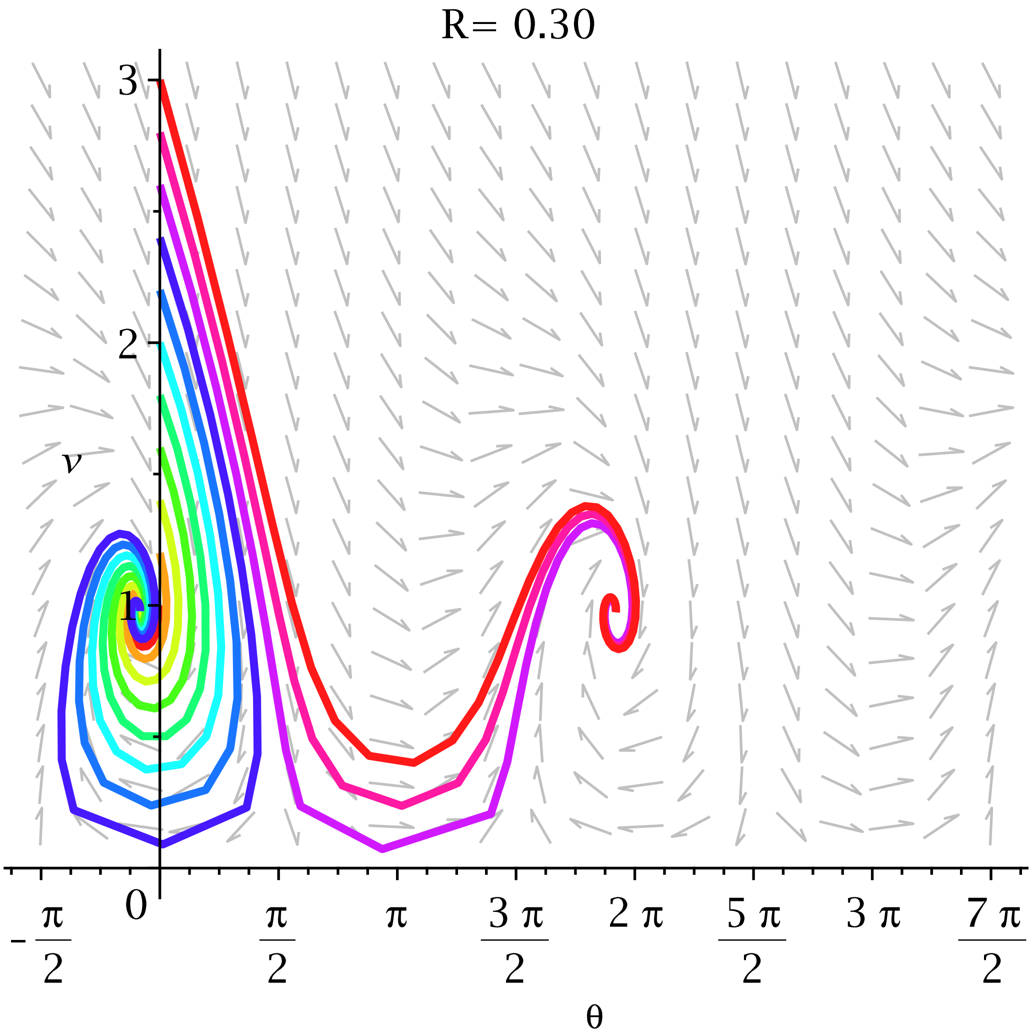


```
> #   I want something like this; need to write a function that
  does it.
  phugpic(.1)
```



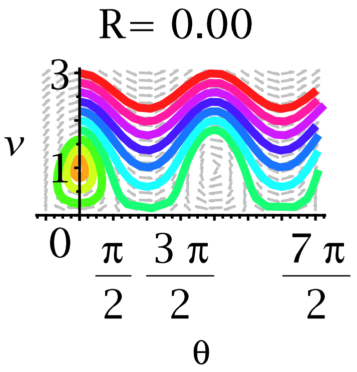
```
> phugpic :=proc(R)
   local theta, v, pic, phug, initv, hval;
   phug := [ D(theta)(t) = v(t) - cos(theta(t))/v(t), D(v)(t) = -sin(theta(t)) - R
     ·v(t)^2];
   pic := DEtools[DEplot]( phug, [theta(t), v(t)], t = 0..10,
    [seq([theta(0) = 0, v(0) = initv], initv = 1..3, .2) ],
     # these are my initial values...
    theta = -Pi/2 .. 7 Pi/2, v = 0..3, tickmarks = [piticks, default],
    linecolor = [seq(COLOR(HUE, hval), hval = 0..1, 0.1) ], color = gray,
    title = sprintf("R=%5.2f", R));
    return(pic);
  end:
```

```
> phugpic(.3)
```

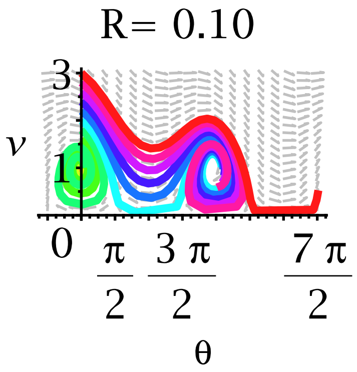


Now that we have a function that generates pictures, we can make a sequence of them

```
> [ seq(phugpic(R), R = 0..0.4, .1) ]
```



,



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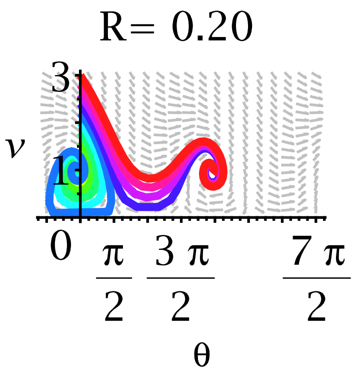
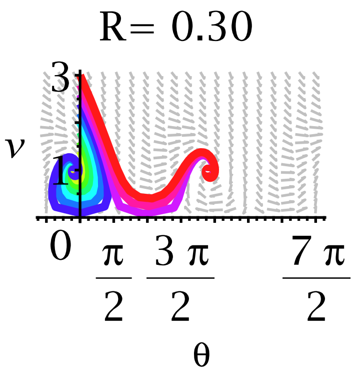


,



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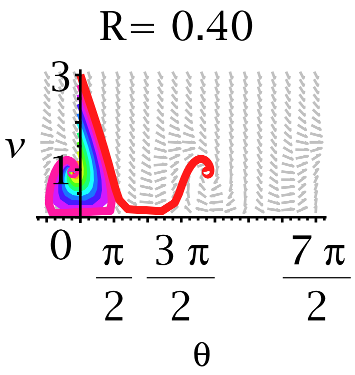


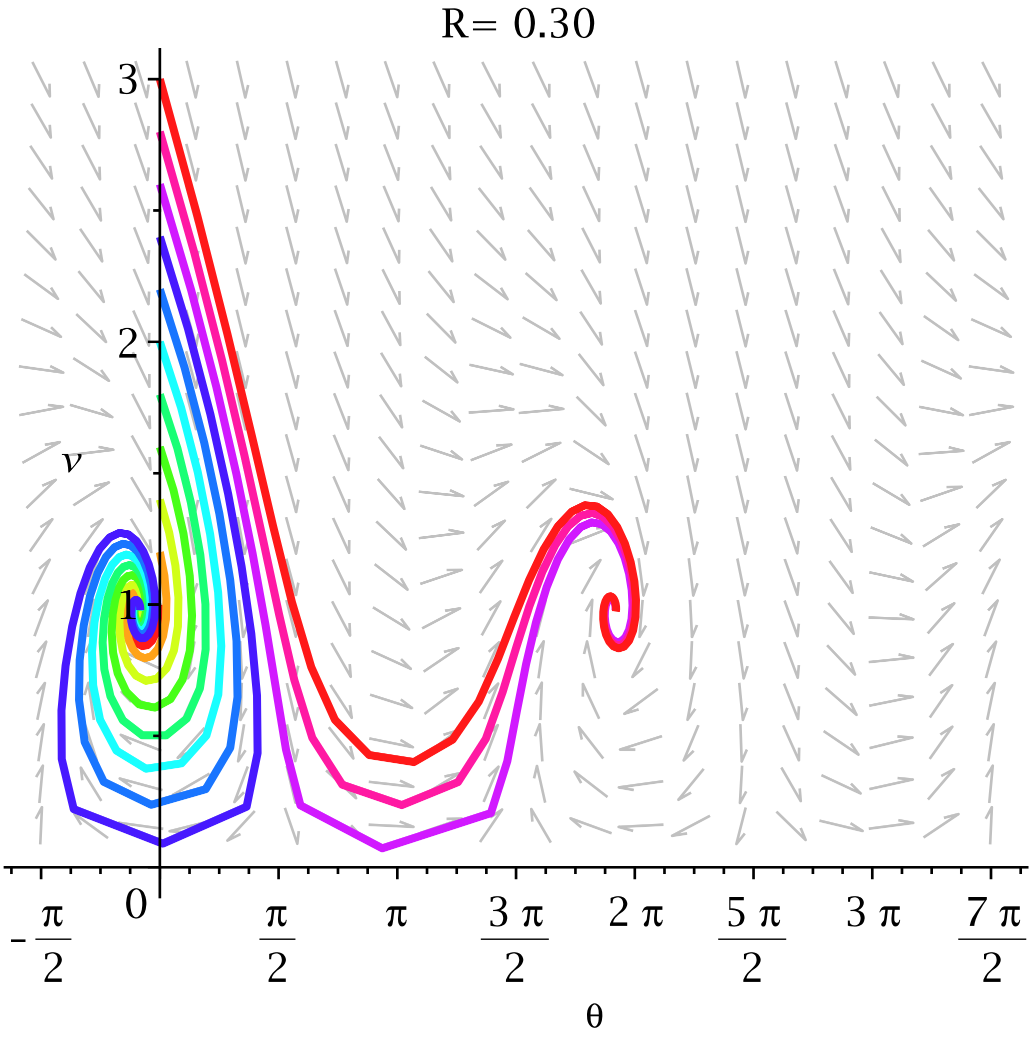
Let's make a movie!!!!

A movie is just a sequence of (still) frames, that we can show one after the other.

```
> frames := [seq(phugpic(R), R = 0..1, .05)]:
```

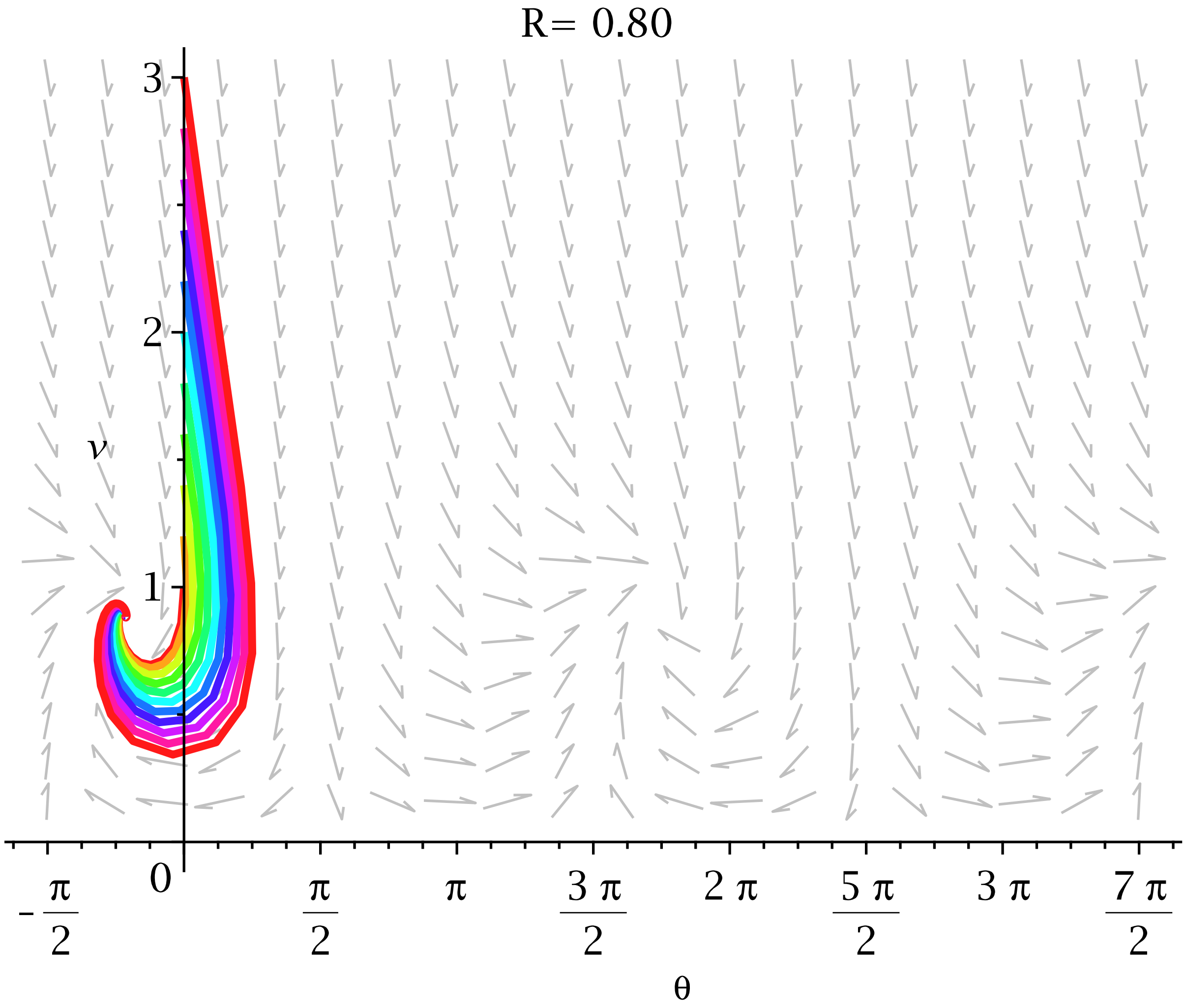
Let's look at one of them, just to see what we have.

```
> frames[7]
```



In order to animate this, we can use the display command from the plots library, which has an option (insequence=true) saying to show the sequence of images as an animation.

```
> with(plots) :
> display(frames, insequence = true)
```



Although the above looks like a single image, if you select it (click on the image), a set of controls appears at the top (or right click, select Animation ... play   from the menu.)