

## VPython Class 5: Phasors and Interference, Part I

### 1. Introduction

Chapter 1 of the PHYS 212 Supplementary Reading is about how we can use rotating arrows, called *phasors*, to represent oscillatory motion. When studying interference and diffraction, as we will do as the next topic in this course, we need to add up, or *superpose*, multiple oscillations; phasors are a great tool for this kind of addition of out-of-phase sine waves.

### 2. Starters: axes and arrows

Let's start by making simple  $x$ - and  $y$ -axes:

```
xaxis = curve(vec(-5, 0, 0), vec(5, 0, 0))
yaxis = curve(vec(0, -5, 0), vec(0, 5, 0))
```

We have used the VPython `arrow` object in our representation of vector fields. Today we are going to use rotating arrows to represent *phasors*, which are tools we will use in the analysis of wave interference. As a reminder, you can make a green arrow of length  $\sqrt{2}$  with its tail at the point  $(2, 1)$ , and pointing up and to the right at a  $45^\circ$  angle, with the command

```
phasor1 = arrow(pos=vec(2, 1, 0), axis=vec(1, 1, 0), color=color.green)
```

Define in amplitude `a1`, and an angle `phi1`, and make an arrow of length `a1` with its tail at the origin, inclined at angle `phi1` with respect to the  $x$ -axis. What should you use for the `axis` of the arrow? Hint: it will involve some trig functions.

### 3. Rotating arrows

To rotate the arrow we need to specify the rotation speed with a variable `omega1`. If you're feeling comfortable with programming, try to make your phasor rotate at the angular frequency `omega1`. If you need some help, turn over the page.

One way to animate the motion of the phasor is a `while` loop — something like

```
omega1 = 2.0
dt = 0.05
while True:
    rate(50)
    phasor1.axis = vec( give the axis vector in terms of a1 and phi1 )
    phi1 = phi1 + omega1*dt
```

Make sure you understand what is happening with `phi1` as a function of time. If you get this right, your phasor arrow should be cheerfully circling around.

## 4. Two phasors

Now go back and modify your program to have two phasors, `phasor1` and `phasor2`, each with their own amplitude (`a1` and `a2`), initial angle (`phi1` and `texttphi2`) rotational velocity (`omega1` and `omega2`). Play with different values for the parameters to make sure your animation is behaving correctly.

## 5. Interference

If these two phasors represent waves that are being combined, such as two sound waves arriving at your ear, or two light waves reaching the screen at a particular point, we can use our phasor diagram to understand the resulting oscillation. Basically, we just have to do a vector addition of the phasors. So let's introduce a third arrow object to represent the sum of the other two arrows. It would be a good idea to make it a different color.

You can create this object, let's call it `phasor_sum`, before the `while` loop. Then inside the `while` loop you can update the sum just by adding the updated vectors for `phasor1` and `phasor2`. That is, you'll want a line like

```
...some while loop stuff...
phasor_sum.axis = phasor1.axis + phasor2.axis
...more while loop stuff...
```

Do you see how this will work? Ask questions if you're unclear on this.

The sum of the phasors represents the interference between the two waves. To help visualize this, create a sphere object that will be the physical oscillator. Make it the same color as `phasor_sum`, and have it to be oscillate back and forth on the  $x$ -axis as the projection of `phasor_sum` onto the  $x$ -axis.

When you think you have all this working, call one of us over to check it over.

## 6. Play time

- Choose two frequencies that are unequal but similar, to observe beats.
- Now set the frequencies to be the same, and play around with the phase difference  $\phi_2 - \phi_1$ . For what values do you get constructive interference? For what values is it destructive?
- What happens if you add a third phasor? What is a choice of  $\phi_1$ ,  $\phi_2$ , and  $\phi_3$  that would give constructive interference? Destructive interference?

When you have working code and have played around with this, write up a short description of what you observed. Include this as a comment in your notebook, and then you can turn it in to my dropbox.