Math 2300: Calc 2 Project: Functions and Graphing with Sage

This tutorial will involve graphing using Sage.

1. Log in to the Sage server at `sage.colorado.edu`, open up a new blank Sage worksheet (by clicking on "New worksheet"), and, when prompted to name the worksheet, call it "Functions_lastname" (where, instead of the literal word "lastname," you enter your actual last name).

   One of the things Sage can do is graph functions given a formula. To plot the function $y = x^2$ on the domain $[-5, 5]$, type the following into the empty "cell" (input box) at the top of your worksheet:

   ```
   plot(x^2,-5,5)
   ```

   and press "Evaluate" or Shift+Enter. (Note that Sage uses a caret "^" for exponents.)

2. Labelling axes is easy. Try entering and executing this, in a new cell:

   ```
   plot(x^2,-2,2,axes_labels=['x','y'])
   ```

   (If you want, do this by copying the code from your previous exercise into a new cell, and modifying as necessary.) How is your new graph different from the previous one?

3. Now suppose that, instead, we wanted to plot the function $s = t^2$. Try entering

   ```
   plot(t^2,-2,2,axes_labels=['t','s'])
   ```

   and executing. What goes wrong?

4. The problem is that, unless you tell Sage otherwise (and you can, but we won't discuss how, at least not yet), it will only plot properly when the independent variable is called x. But that's OK, we can "trick" Sage into plotting $s = t^2$, by calling the independent variable x, but labelling our axes otherwise. Try this:

```
plot(x^2,-2,2,axes_labels=['t','s'])
```

5. In mathematics, it's traditional to *italicize* variable names. To do this in the axes labels on a Sage plot, put dollar signs around these names. Try this:

```
plot(x^2,-2,2,axes_labels=['$t$','$s$'])
```

6. Now suppose that, instead of simply putting a t on the horizontal axis and an s on the vertical axis, we want to write "t (seconds)" on the horizontal axis, and "s (meters)" on the vertical axis. By cutting, pasting, and modifying your code from the previous exercise, enter and execute code that will do exactly this. (Careful: you want to italicize the t and the s, but nothing else.)

7. Plotting two or more functions is easy; just put plus signs between the "plot" commands. It's nice to know which function is which, so we'll also add some color. For example, we'll plot the two functions

$$f(x) = x^2 \text{ (in blue)} \qquad \text{and} \qquad g(x) = 3x - 2 \text{ (in red)}$$

by evaluating the code

```
plot(x^2,-1,3,color='blue',axes_labels=['$x$','$y$'])
+plot(3*x-2,-1,3,color='red')
```

(put it all on one line; it wouldn't fit here). Note that Sage uses an asterisk "`*`" for multiplication: you can't just type in `3x`. Also NOTE THAT YOU ONLY HAVE TO LABEL THE AXES IN ONE OF THE TWO "PLOT" COMMANDS!!!!!

8. Where do the graphs of the above functions $f(x) = x^2$ and $g(x) = 3x - 2$ appear to intersect? How would you verify this algebraically?

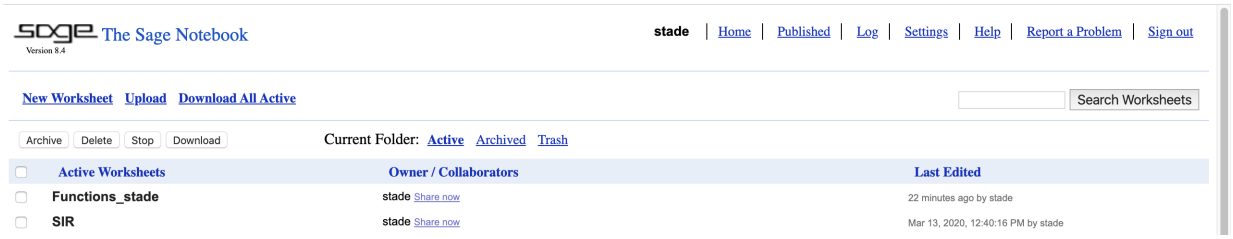
9. Sage can plot trigonometric functions too. By default, the domain is always in radians, so in order to see two cycles of the sine function, you could type

   ```
   plot(sin(x),-2*pi,2*pi)
   ```

   Go ahead and try this.

10. Try plotting three or more functions at a time, all on the same domain, and each in a different color. (You can cut and paste from the entries above, but make sure you make the necessary adjustments to get the same domain but different colors. What happens if you DON'T specify the same domain for all three functions?)

11. When you're done with the above, press the "Save & quit" button at the top of your worksheet. You will be taken back to your directory of files, and you should see your "Functions_lastname" worksheet at the top, like this:



In the "Owners/collaborators" space to the right of the file name, click on "Share now." In the box that appears, enter *my* username, which is "stade." Then click on "Update collaborators." You will have shared your file with me, so I can see that you have done the work.

You're done!!