# Introduction to Sage                              Math 141 - Workshop

Sage is a free Computer Algebra System that is available online. To access Sage, go to the website:

https://sagecell.sagemath.org/

1. **Evaluating Expressions** Enter the function $f(x) = \dfrac{2x^2}{x^2 - 1}$ into Sage. Remember, you have to use $*$ to indicate multiplication. Then evaluate:

   (a) $f(2)$

   (b) $f(2.5)$

   (c) $f(\pi)$ (enter `pi` for $\pi$)

   To see the output of each of these commands use the `print( )` function (put the expression you want to print inside the parentheses). Notice how the type of output (fraction or decimal) depends on the input you provide. To convert an exact answer (like the ones in parts (a) and (c)) to a decimal, you can use the `N( )` function (`N` for numerical).

2. **Evaluating Multiple Values** You can evaluate a function at several values, all at once. Enter `g(x) = 1/sqrt(x)` to input the function $g(x) = \dfrac{1}{\sqrt{x}}$.

   (a) Try the following command:

   $$[g(x) \text{ for x in } [1,2,3,4]]$$

   (b) Notice that Sage only computes the function if it can give an exact answer. One way to get decimal number outputs is to use decimal inputs. Try this:

   $$[g(x) \text{ for x in } [1.0,2.0,3.0,4.0]]$$

   (c) You can also list both $x$ and $y$ coordinates simultaneously:

   $$[(x,g(x)) \text{ for x in } [1,2,3,4]]$$

3. **Variables** Try entering the function $V = \frac{4}{3}\pi r^3$ into Sage. In order to do this, you have to define the variable $r$ first with the command `var('r')`. All variables other than $x$ have to be defined this way.

   (a) Use the command `diff(V,r)` to find the derivative of $V$ with respect to $r$. What happens if you only type `diff(V)`?

   (b) Now try to enter the volume of a cylinder formula $V = \pi r^2 h$. You can use the command `var('r,h')` to define both variables at once. What happens if you try `diff(V)` for this formula?

4. **Expanding and Factoring** Use the functions `expand( )` and `factor( )` to simplify the following expressions.

   (a) $x^3 - 2x^2 - 11x + 12$

   (b) $(x - 3)(x^2 + 5)(x^3 - 1)$

5. **Putting It Together** Use Sage to completely analyze the following functions. Describe the intervals of increase/decrease, concavity, inflection points, asymptotes, etc.

   (a) $y = x^2 - 5x + 8 - \dfrac{5}{x} + \dfrac{1}{x^2}$

   (b) $f(x) = \dfrac{x}{\sqrt{x^2 + 1}}$

   (c) $f(x) = x^2 \sqrt{c^2 - x^2}$

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## Things to Keep in Mind

Sage is very powerful, but it isn't as user friendly as some other math software. In Sage, the way you enter expressions matters. Watch out for these common mistakes:

- You have to use $*$ to indicate multiplication. Sage won't understand `2x`.

- Sage is rigid about order of operations (powers before multiplication, multiplication before addition, etc.). If you aren't sure, use extra parentheses!

- Avoid extra spaces in expressions. For example `f(x)` is okay, but `f (x)` is not.

- Sage is case-sensitive (capital letters and lower-case letters are not the same).

- Look out for mismatched parentheses.

- All variables (except $x$) have to be defined using the `var( )` function.

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