

## Sample Computations with Sage

When you load up your Sage notebook, you will see your existing worksheets and the "New Worksheet" button on the top of the page. Once you click it, you name your new worksheet and you're off.

First, you see a blinking cursor, this is where you type in the Sage commands. Now you type in stuff and press evaluate. I'll just run through some examples.

Let's say you want to do some simple calculations:

```
sage: 33+4
%= 37
```

```
sage: 33/17
%= 33/17
```

```
sage: 144/12
%= 12
```

Notice that Sage doesn't turn fractions into decimals. If you multiply a fraction by 1.0, it'll become a decimal, but not otherwise.

Sage can also do some more exotic things. Let's say you want to know 33!

```
sage: factorial(33)
%= 8683317618811886495518194401280000000
```

Or maybe you want to factor  $(22! + 10!)$

```
sage: factor(factorial(22)+factorial(10))
%= 2^8 * 3^4 * 5^2 * 7 * 307 * 3851 * 261994193
```

Another useful function is `xgcd(a,b)`, which returns  $(d, r, s)$  so that  $a*r+b*s=d$  and  $d=\text{gcd}(a,b)$ . In other words, it gives you the output of the extended Euclidean algorithm.

```
sage: xgcd(32, 37)
%= [1, -15, 13]
```

To work with integers modulo  $n$ , you refer to " $a \pmod n$ " as "`Mod(a,n)`". (SAGE is case-sensitive, but "`Mod`" and "`mod`" are the same command)

```
sage: Mod(3,7)*Mod(4,7)
5 %mod7
```

```
sage: Mod(3,7)^6
%= 1 %mod7
```

```
sage: Mod(13333,12)
%= 1 %mod12
```

```
sage: Mod(22,37)^(-1)
%= 32 %mod37
```

It's important to note that computers are very literal-minded. Sage will do what you tell it to do. An example is  $\text{Mod}(5^{30000},12)$  versus  $\text{Mod}(5,12)^{30000}$ . The first says "compute  $5^{30000}$ , then reduce it modulo 12"; the second says "reduce 5 modulo 12, then compute the 30000th power of that". In the first computation  $5^{30000}$  is computed *as an integer* first. In the second, Sage works mod 12 throughout. Guess which takes longer? OK, that should get you started. A lot of the computations you may need to do in this course can be done in Sage, so it's a useful tool.

Also, there is a helpful tool to know what a command does or to know about similar commands. Type the first few letters of the command into the prompt, then press [tab]. A list appears with all commands matching those letters, scroll through to the one you are interested in knowing about and press [tab] again, a detailed description of the command displays in the worksheet.