
Installation Guide

Release 10.1

The Sage Development Team

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If you are reading this manual at <https://doc.sagemath.org/>, note that it was built at the time the most recent stable release of SageMath was made.

More up-to-date information and details regarding supported platforms may have become available afterwards and can be found in the section “Availability and installation help” of the [release tour](#) for each SageMath release.

Where would you like to run SageMath? Pick one of the following sections.

- **Do you want to do SageMath development?**

- **Yes, development:**

- Obtain the SageMath sources via `git` as described in [The Sage Developer's Guide](#).

- * Then build SageMath from source as described in section [Install from Source Code](#).
 - * Alternatively, follow the instructions in section [Using conda to provide all dependencies for the Sage library \(experimental\)](#); these describe an experimental method that gets all required packages, including Python packages, from conda-forge.

- **No development:**

- * Install the [binary build of SageMath](#) from the 3-manifolds project. It is a signed and notarized app, which works for macOS 10.12 and newer. It is completely self-contained and provides the standard Sage distribution together with many optional packages. Additional optional Python packages can be installed with the `%pip` magic command and will go into your `~/ .sage` directory.
 - * Alternatively, install SageMath from the [conda-forge](#) project, as described in section [Install from conda-forge](#).
 - * Alternatively, build SageMath from source as described in section [Install from Source Code](#).

WINDOWS

- **Do you want to do SageMath development?**

- **Yes, development:**

Enable Windows Subsystem for Linux (WSL) by following the [official WSL setup guide](#). Be sure to do the steps to install WSL2 and set it as default. Make sure to allocate enough RAM to WSL: 5GB is known to be enough, 2GB might not allow you to build some packages. Then go to the Microsoft Store and install Ubuntu (or another Linux distribution). Start Ubuntu from the start menu.

Then follow the instructions for development on Linux below.

- **No development:**

- * Enable Windows Subsystem for Linux (WSL) by following the [official WSL setup guide](#). Be sure to do the steps to install WSL2 and set it as default. Make sure to allocate enough RAM to WSL: 5GB is known to be enough, 2GB might not allow you to build some packages. Then go to the Microsoft Store and install Ubuntu (or another Linux distribution). Start Ubuntu from the start menu.

On the Linux running on WSL, you always have root access, so you can use any of the installation methods described below for Linux.

- **Do you want to do SageMath development?**

- **Yes, development:**

- Obtain the SageMath sources via `git` as described in [The Sage Developer's Guide](#).

- * Then build SageMath from source as described in section [Install from Source Code](#).

- * Alternatively, follow the instructions in section [Using conda to provide all dependencies for the Sage library \(experimental\)](#); these describe an experimental method that gets all required packages, including Python packages, from conda-forge.

- No development: **Do you have root access (sudo)?**

- * **Yes, root access:** Then the easiest way to install SageMath is through a Linux distribution that provides it as a package. Most major Linux distributions have up-to-date versions of SageMath, see [repology.org: sagemath](http://repology.org:sagemath) for an overview. See [Linux package managers](#) for additional information.

- If you are on an older version of your distribution and a recent version of SageMath is only available on a newer version of the distribution, consider upgrading your distribution. In particular, do not install a version of Sage older than 9.2.

- * **No root access, or on an older distribution** Install SageMath from the [conda-forge](#) project, as described in section [Install from conda-forge](#).

- * Alternatively, build SageMath from source as described in section [Install from Source Code](#).

IN THE CLOUD

- **CoCalc**: an online service that provides SageMath and many other tools.
- On any system that allows you to bring your own Docker images to run in a container: Use the [Docker image sagemathinc/cocalc](#) or another [Docker image providing SageMath](#).
- **Sage Cell Server**: an online service for elementary SageMath computations.

More information:

4.1 Linux package managers

SageMath is available from various distributions and can be installed by package managers.

See the [_sagemath dummy package](#) for the names of packages that provide a standard installation of SageMath, including documentation and Jupyter.

See also [repology.org: sagemath](#) for information about versions of SageMath packages in various distributions. **Do not install a version of Sage older than 9.2.** If you are on an older version of your distribution and a recent version of SageMath is only available on a newer version of the distribution, consider upgrading your distribution.

Gentoo users might want to give a try to [sage-on-gentoo](#).

The *GitHubwikipageDistribution* < <https://github.com/sagemath/sage/wiki/Distribution> > collects information regarding packaging and distribution of SageMath.

4.2 Install from Pre-built Binaries

4.2.1 Linux

SageMath used to provide pre-built binaries for several Linux flavors. This has been discontinued, as most major Linux distributions have up-to-date distribution packages providing SageMath. See [Linux package managers](#) for information.

4.2.2 macOS

macOS binaries are available from the [3-manifolds project](#). These have been signed and notarized, eliminating various errors caused by Apple's gatekeeper antimalware protections.

SageMath used to provide pre-built binaries for macOS on its mirrors. This has been discontinued, and the old binaries that are still available there are no longer supported.

4.2.3 Microsoft Windows

SageMath used to provide pre-built binaries for Windows based on Cygwin. This has been discontinued, and the old binaries that can be found are no longer supported. Use Windows Subsystem for Linux instead.

4.3 Install from conda-forge

SageMath can be installed on Linux and macOS via Conda from the [conda-forge](#) conda channel.

Both the x86_64 (Intel) architecture and the arm64/aarch64 architectures (including Apple Silicon, M1) are supported.

You will need a working Conda installation: either Mambaforge/Miniforge, Miniconda or Anaconda. If you don't have one yet, we recommend installing [Mambaforge](#) as follows. In a terminal,

```
$ curl -L -O https://github.com/conda-forge/miniforge/releases/latest/download/  
↳Mambaforge-$(uname)-$(uname -m).sh  
$ sh Mambaforge-$(uname)-$(uname -m).sh
```

- Mambaforge and Miniforge use conda-forge as the default channel.
- If you are using Miniconda or Anaconda, set it up to use conda-forge:
 - Add the conda-forge channel: `conda config --add channels conda-forge`
 - Change channel priority to strict: `conda config --set channel_priority strict`

Optionally, use [mamba](#), which uses a faster dependency solver than conda. If you installed Mambaforge, it is already provided. Otherwise, use

```
$ conda install mamba
```

4.3.1 Installing all of SageMath from conda (not for development)

Create a new conda environment containing SageMath, either with `mamba` or `conda`:

```
$ mamba create -n sage sage python=X           # either  
$ conda create -n sage sage python=X         # or
```

where `X` is version of Python, e.g. 3.9.

To use Sage from there,

- Enter the new environment: `conda activate sage`
- Start SageMath: `sage`

If there are any installation failures, please report them to the conda-forge maintainers by opening a [GitHub Issue](#) for `conda-forge/sage-feedstock`.

4.3.2 Using conda to provide system packages for the Sage distribution

If Conda is installed (check by typing `conda info`), one can install SageMath from source as follows:

- If you are using a git checkout:

```
$ ./bootstrap-conda
```

- Create a new conda environment including all standard packages recognized by sage, and activate it:

```
$ conda env create --file environment.yml --name sage-build
$ conda activate sage-build
```

Alternatively, use `environment-optional.yml` in place of `environment.yml` to create an environment with all standard and optional packages recognized by sage.

- Then the SageMath distribution will be built using the compilers provided by Conda and using many packages installed by Conda:

```
$ ./bootstrap
$ ./configure --with-python=$CONDA_PREFIX/bin/python \
              --prefix=$CONDA_PREFIX
$ make
```

4.3.3 Using conda to provide all dependencies for the Sage library (experimental)

You can build and install the Sage library from source, using conda to provide all of its dependencies. This bypasses most of the build system of the Sage distribution and is the fastest way to set up an environment for Sage development.

Note that this is still an experimental feature and may not work as intended.

Here we assume that you are using a git checkout.

- Optionally, set the build parallelism for the Sage library. Use whatever the meaningful value for your machine is - no more than the number of cores:

```
$ export SAGE_NUM_THREADS=24
```

- As a recommended step, install the mamba package manager. If you skip this step, replace `mamba` by `conda` in the following steps:

```
$ conda install mamba
```

- Generate the conda environment files `src/environment*.yml` used in the next step:

```
$ ./bootstrap-conda
```

- Create and activate a new conda environment with the dependencies of Sage and a few additional developer tools:

```
$ mamba env create --file src/environment-dev.yml --name sage-dev
$ conda activate sage-dev
```

Alternatively, you can use `src/environment.yml` or `src/environment-optional.yml`, which will only install standard (and optional) packages without any additional developer tools.

By default, the most recent version of Python supported by Sage is installed. You can use the additional option `python=3.9` in the above `env create` command to select another Python version (here 3.9).

- Run the configure script:

```
$ ./bootstrap
$ ./configure --with-python=$CONDA_PREFIX/bin/python \
              --prefix=$CONDA_PREFIX \
              $(for pkg in $(./sage -package list :standard: \
                           --exclude rpy2 \
                           --has-file spkg-configure.m4 \
                           --has-file distros/conda.txt); do \
                  echo --with-system-$pkg=force; \
              done)
```

- Install the build prerequisites and the Sage library:

```
$ pip install --no-build-isolation -v -v --editable ./pkgs/sage-conf ./pkgs/sage-
↪setup
$ pip install --no-build-isolation -v -v --editable ./src
```

- Verify that Sage has been installed:

```
$ sage -c 'print(version())'
SageMath version 9.6.beta5, Release Date: 2022-03-12
```

Note that `make` is not used at all. All dependencies (including all Python packages) are provided by `conda`.

Thus, you will get a working version of Sage much faster. However, note that this will invalidate the use of any Sage-the-distribution commands such as `sage -i`. Do not use them.

By using `pip install --editable` in the above steps, the Sage library is installed in editable mode. This means that when you only edit Python files, there is no need to rebuild the library; it suffices to restart Sage.

After editing any Cython files, rebuild the Sage library using:

```
$ pip install --no-build-isolation -v -v --editable src
```

In order to update the `conda` environment later, you can run:

```
$ mamba env update --file src/environment-dev.yml --name sage-dev
```

To build the documentation, use:

```
$ pip install --no-build-isolation -v -v --editable ./pkgs/sage-docbuild
$ sage --docbuild all html
```

4.4 Install from Source Code

Table of contents

- *Install from Source Code*
 - *Prerequisites*
 - *Additional software*
 - *Step-by-step installation procedure*
 - *Make targets*
 - *Environment variables*
 - *Installation in a Multiuser Environment*

Some familiarity with the use of the Unix command line may be required to build Sage from the [source code](#).

Building Sage from the source code has the major advantage that your install will be optimized for your particular computer and should therefore offer better performance and compatibility than a binary install.

Moreover, it offers you full development capabilities: you can change absolutely any part of Sage or the programs on which it depends, and recompile the modified parts.

See the file [README.md](#) in `SAGE_ROOT` for information on supported platforms and step-by-step instructions.

The following sections provide some additional details. Most users will not need to read them.

4.4.1 Prerequisites

Disk space and memory

Your computer comes with at least 6 GB of free disk space. It is recommended to have at least 2 GB of RAM, but you might get away with less (be sure to have some swap space in this case).

Software prerequisites and recommended packages

Sage depends on a [large number of software packages](#). Sage provides its own software distribution providing most of these packages, so you do not have to worry about having to download and install these packages yourself.

If you extracted Sage from a source tarball, the subdirectory `upstream` contains the source distributions for all standard packages on which Sage depends. If cloned from a git repository, the upstream tarballs will be downloaded, verified, and cached as part of the Sage installation process.

However, there are minimal prerequisites for building Sage that already must be installed on your system:

- [Fundamental system packages required for installing from source](#)
- [C/C++ compilers](#)

If you have sufficient privileges (for example, on Linux you can use `sudo` to become the root user), then you can install these packages using the commands for your platform indicated in the pages linked above. If you do not have the privileges to do this, ask your system administrator to do this for you.

In addition to these minimal prerequisites, we strongly recommend to use system installations of the following:

- [Fortran compiler](#)

- Python

Sage developers will also need the [system packages required for bootstrapping](#); they cannot be installed by Sage.

When the `./configure` script runs, it will check for the presence of many packages (including the above) and inform you of any that are missing or have unsuitable versions. **Please read the messages that `./configure` prints:** It will inform you which additional system packages you can install to avoid having to build them from source. This can save a lot of time.

The following sections provide the commands to install a large recommended set of packages on various systems, which will minimize the time it takes to build Sage. This is intended as a convenient shortcut, but of course you can choose to take a more fine-grained approach.

Debian/Ubuntu package installation

On Debian (“buster” or newer) or Ubuntu (“bionic” or newer), we recommend that you install:

```
$ sudo apt-get install bc binutils bzip2 ca-certificates cliquer cmake curl ecl eclib-
↳tools fflas-ffpack g++ gcc gengetopt gfan gfortran glpk-utils gmp-ecm lcalc libatomic-
↳ops-dev libboost-dev libbraiding-dev libbrial-dev libbrial-groebner-dev libbz2-dev
↳libcdd-dev libcdd-tools libcliquer-dev libcurl4-openssl-dev libec-dev libecm-dev
↳libffi-dev libflint-arb-dev libflint-dev libfp11l-dev libfreetype6-dev libgc-dev libgd-
↳dev libgf2x-dev libgiac-dev libgivaro-dev libglpk-dev libgmp-dev libgsl-dev libhomfly-
↳dev libiml-dev liblfunction-dev liblinbox-dev liblrcalc-dev liblzma-dev libm4ri-dev
↳libm4rie-dev libmpc-dev libmpfi-dev libmpfr-dev libncurses5-dev libntl-dev libopenblas-
↳dev libpari-dev libplanarity-dev libppl-dev libprimesieve-dev libpython3-dev libqhull-
↳dev libreadline-dev librw-dev libsingular4-dev libsqlite3-dev libssl-dev
↳libsuitesparse-dev libsymmetrca2-dev libz-dev libzmq3-dev m4 make maxima maxima-sage
↳meson nauty ninja-build openssl palp pari-doc pari-elldata pari-galdata pari-galpol
↳pari-gp2c pari-seadata patch perl pkg-config planarity ppl-dev python3 python3-
↳distutils python3-venv singular singular-doc sqlite3 sympow tachyon tar texinfo tox
↳xcas xz-utils
```

If you wish to do Sage development, we recommend that you additionally install the following:

```
$ sudo apt-get install autoconf automake gh git gpgconf libtool openssl-client pkg-
↳config
```

For all users, we recommend that you install the following system packages, which provide additional functionality and cannot be installed by Sage:

```
$ sudo apt-get install default-jdk dvipng ffmpeg imagemagick latexmk libavdevice-dev
↳pandoc tex-gyre texlive-fonts-recommended texlive-lang-cyrillic texlive-lang-english
↳texlive-lang-european texlive-lang-french texlive-lang-german texlive-lang-italian
↳texlive-lang-japanese texlive-lang-polish texlive-lang-portuguese texlive-lang-spanish
↳texlive-latex-extra texlive-xetex
```

In addition to these, if you don’t want Sage to build optional packages that might be available from your OS, cf. the growing list of such packages on [github issue #27330](#), install:

```
$ sudo apt-get install 4ti2 clang coinor-cbc coinor-libcbc-dev graphviz libfile-slurp-
↳perl libgraphviz-dev libigraph-dev libisl-dev libjson-perl libmongod-perl libnauty-
↳dev libperl-dev libpolymake-dev libsvg-perl libtbb-dev libterm-readkey-perl libterm-
↳readline-gnu-perl libxml-libxslt-perl libxml-writer-perl libxml2-dev lrslib pari-gp2c
↳pdf2svg polymake r-base-dev r-cran-lattice
```

Fedora/Redhat/CentOS package installation

On Fedora/Redhat/CentOS, we recommend that you install:

```
$ sudo yum install --setopt=tsflags=L-function L-function-devel Singular Singular-
→devel arb arb-devel binutils boost-devel brial brial-devel bzip2 bzip2-devel cddlib
→cliquer cliquer-devel cmake curl diffutils ecl eclib eclib-devel fflas-ffpack-devel
→findutils flint flint-devel gc gc-devel gcc gcc-c++ gcc-gfortran gd gd-devel gengetopt
→gf2x gf2x-devel gfan giac giac-devel givaro givaro-devel glpk glpk-devel glpk-utils
→gmp gmp-devel gmp-ecm gmp-ecm-devel gsl gsl-devel iml iml-devel info libatomic_ops
→libatomic_ops-devel libbraiding libcurl-devel libffi libffi-devel libfp111 libfp111-
→devel libhomfly-devel libmpc libmpc-devel linbox lrcalc-devel m4 m4ri-devel m4rie-
→devel make meson mpfr-devel nauty ncurses-devel ninja-build ntl-devel openblas-devel
→openssl openssl-devel palp pari-devel pari-elldata pari-galdata pari-galpol pari-gp
→pari-seadata patch perl perl-ExtUtils-MakeMaker perl-IPC-Cmd pkg-config planarity
→planarity-devel ppl ppl-devel primecount primecount-devel primesieve primesieve-devel
→python3 python3-devel qhull qhull-devel readline-devel rw-devel sqlite sqlite-devel
→suitesparse suitesparse-devel symmetrica-devel sympow tachyon tachyon-devel tar
→texinfo tox which xz xz-devel zeromq zeromq-devel zlib-devel
```

If you wish to do Sage development, we recommend that you additionally install the following:

```
$ sudo yum install autoconf automake gh git gnupg2 libtool openssh pkg-config
```

For all users, we recommend that you install the following system packages, which provide additional functionality and cannot be installed by Sage:

```
$ sudo yum install ImageMagick latexmk pandoc texlive texlive-collection-langcyrillic
→texlive-collection-langeuropean texlive-collection-langfrench texlive-collection-
→langgerman texlive-collection-langitalian texlive-collection-langjapanese texlive-
→collection-langpolish texlive-collection-langportuguese texlive-collection-langspanish
→texlive-collection-latexextra
```

In addition to these, if you don't want Sage to build optional packages that might be available from your OS, cf. the growing list of such packages on [github issue #27330](#), install:

```
$ sudo yum install 4ti2 R R-devel clang coin-or-Cbc coin-or-Cbc-devel coxeter coxeter-
→devel coxeter-tools graphviz igraph igraph-devel isl-devel libnauty-devel libxml2-
→devel lrslib pari-galpol pari-seadata pdf2svg perl-ExtUtils-Embed perl-File-Slurp perl-
→JSON perl-MongoDB perl-Term-ReadLine-Gnu perl-TermReadKey perl-XML-LibXML perl-XML-
→LibXSLT perl-XML-Writer polymake tbb-devel
```

Arch Linux package installation

On ArchLinux, we recommend that you install:

```
$ sudo pacman -S arb bc binutils boost brial cblas cddlib cmake ecl eclib fflas-
→ffpack gc gcc gcc-fortran gd gf2x gfan giac glpk gsl iml lapack lcalc libatomic_ops
→libbraiding libgiac libhomfly linbox lrcalc m4 m4ri m4rie make maxima-fas meson nauty
→ninja openblas openssl palp pari pari-elldata pari-galdata pari-galpol pari-seadata
→patch perl planarity ppl primecount primesieve python python-tox qhull rankwidth
→readline singular sqlite3 suitesparse symmetrica sympow tachyon tar which zeromq
```

If you wish to do Sage development, we recommend that you additionally install the following:

```
$ sudo pacman -S autoconf automake git github-cli gnupg libtool openssh pkg-config
```

For all users, we recommend that you install the following system packages, which provide additional functionality and cannot be installed by Sage:

```
$ sudo pacman -S ffmpeg imagemagick pandoc texlive-core texlive-langcyrillic texlive-  
↳langjapanese texlive-latexextra
```

In addition to these, if you don't want Sage to build optional packages that might be available from your OS, cf. the growing list of such packages on [github issue #27330](#), install:

```
$ sudo pacman -S 4ti2 clang coin-or-cbc coxeter graphviz igraph intel-oneapi-tbb  
↳libxml2 lrs pari-elldata pari-galpol pari-seadata pdf2svg perl-term-readline-gnu  
↳polymake r
```

OpenSUSE package installation

On OpenSUSE, we recommend that you install:

```
$ sudo zypper install arb-devel bc binutils boost-devel brial-devel bzip2 ca-  
↳certificates cddlib-tools cliquer cliquer-devel cmake curl diffutils edge-addition-  
↳planarity-suite edge-addition-planarity-suite-devel findutils flint-devel fplll fplll-  
↳devel gcc gcc-c++ gcc-fortran gd gfan giac-devel glibc-locale-base glpk glpk-devel gmp-  
↳devel gzip iml-devel libbraiding-devel libhomfly-devel libopenssl-3-devel  
↳libprimecount-devel m4 make maxima-exec-clisp meson mpc-devel mpfi-devel nauty nauty-  
↳devel ninja ntl-devel openblas-devel pari-devel pari-galdata pari-gp patch perl  
↳pkgconf pkgconfig(atomic_ops) pkgconfig(bdw-gc) pkgconfig(bzip2) pkgconfig(cddlib)  
↳pkgconfig(fflas-ffpack) pkgconfig(fplll) pkgconfig(freetype2) pkgconfig(gdlib)  
↳pkgconfig(gf2x) pkgconfig(givaro) pkgconfig(gsl) pkgconfig(libcurl) pkgconfig(libffi)  
↳pkgconfig(liblzma) pkgconfig(libpng16) pkgconfig(libzmq) pkgconfig(linbox)  
↳pkgconfig(m4ri) pkgconfig(m4rie) pkgconfig(mpfr) pkgconfig(ncurses)  
↳pkgconfig(ncursesw) pkgconfig(readline) pkgconfig(sqlite3) pkgconfig(zlib) ppl-devel  
↳primecount primesieve python3 python3-devel qhull-devel readline-devel suitesparse-  
↳devel sympow tachyon tar texinfo which xz
```

If you wish to do Sage development, we recommend that you additionally install the following:

```
$ sudo zypper install autoconf automake gh git gpg2 libtool openssh pkgconfig
```

For all users, we recommend that you install the following system packages, which provide additional functionality and cannot be installed by Sage:

```
$ sudo zypper install ImageMagick ffmpeg pandoc texlive
```

In addition to these, if you don't want Sage to build optional packages that might be available from your OS, cf. the growing list of such packages on [github issue #27330](#), install:

```
$ sudo zypper install 4ti2 4ti2-devel R-base coxeter gp2c graphviz libxml2 llvm lrslib  
↳lrslib-devel pari-elldata pari-galpol pari-nftables pari-seadata pdf2svg  
↳perl(Term::ReadLine::Gnu) pkgconfig(isl) pkgconfig(libsemigroups) polymake tbb
```

macOS prerequisites

On macOS systems, you need a recent version of [Command Line Tools](#). It provides all the above requirements.

Run the command `xcode-select --install` from a Terminal window and click “Install” in the pop-up dialog box.

If you have already installed [Xcode](#) (which at the time of writing is freely available in the Mac App Store, or through <https://developer.apple.com/downloads/> provided you registered for an Apple Developer account), you can install the command line tools from there as well.

If you have not installed [Xcode](#) you can get these tools as a relatively small download, but it does require a registration.

- First, you will need to register as an Apple Developer at <https://developer.apple.com/register/>.
- Having done so, you should be able to download it for free at <https://developer.apple.com/downloads/index.action?command%20line%20tools>
- Alternately, <https://developer.apple.com/opensource/> should have a link to Command Line Tools.

macOS package installation

If you use the [Homebrew package manager](#), you can install the following:

```
$ brew install arb bdw-gc boost bzip2 cddlib cmake curl ecl flint fplll freetype gcc_
↪gd gengetopt gfortran glpk gmp gpatch gsl libatomic_ops libffi libiconv libmpc libpng_
↪maxima meson mpfi mpfr nauty ncurses ninja ntl openblas openssl pari pari-elldata pari-
↪galdata pari-galpol pari-seadata pkg-config ppl primecount primesieve python3 qhull_
↪readline singular sqlite suite-sparse texinfo tox xz zeromq zlib
```

Some Homebrew packages are installed “keg-only,” meaning that they are not available in standard paths. To make them accessible when building Sage, run

```
$ source SAGE_ROOT/.homebrew-build-env
```

(replacing `SAGE_ROOT` by Sage’s home directory). You can add a command like this to your shell profile if you want the settings to persist between shell sessions.

If you wish to do Sage development, we recommend that you additionally install the following:

```
$ brew install autoconf automake gh git gnupg libtool pkg-config
```

For all users, we recommend that you install the following system packages, which provide additional functionality and cannot be installed by Sage:

```
$ brew install ffmpeg imagemagick pandoc texinfo
```

Some additional optional packages are taken care of by:

```
$ brew install apaffenholz/polymake/polymake cbc graphviz igraph isl libxml2 llvm_
↪nauty pdf2svg r tbb
```

WSL prerequisites

Ubuntu on Windows Subsystem for Linux (WSL) prerequisite installation

Sage can be installed onto Linux running on Windows Subsystem for Linux (WSL). These instructions describe a fresh install of Ubuntu 20.10, but other distributions or installation methods should work too, though have not been tested.

- Enable hardware-assisted virtualization in the EFI or BIOS of your system. Refer to your system (or motherboard) maker's documentation for instructions on how to do this.
- Set up WSL by following the [official WSL setup guide](#). Be sure to do the steps to install WSL2 and set it as default.
- Go to the Microsoft Store and install Ubuntu.
- Start Ubuntu from the start menu. Update all packages to the latest version.
- Reboot the all running WSL instances one of the following ways:
 - Open Windows Services and restart the LxssManager service.
 - Open the Command Prompt or Powershell and enter this command:

```
wsl --shutdown
```

- Upgrade to the [Ubuntu 20.10](#). This step will not be necessary once Ubuntu 20.10 is available in the Microsoft Store.

From this point on, follow the instructions in the [Debian/Ubuntu package installation](#) section. It is strongly recommended to put the Sage source files in the Linux file system, for example, in the `/home/username/sage` directory, and not in the Windows file system (e.g. `/mnt/c/...`).

WSL permission denied error when building *packaging* package.

You may encounter permission errors of the kind "[Errno 13] Permission denied: 'build/bdist.linux-x86_64/wheel/<package>.dist-info'" during make. This usually comes from a permission conflict between the Windows and Linux file system. To fix it create a temporary build folder in the Linux file system using `mkdir -p ~/tmp/sage` and use it for building by `eval SAGE_BUILD_DIR="~/tmp/sage" make`. Also see the [related Github issue](#) for other workarounds.

WSL post-installation notes

When the installation is complete, you may be interested in [WSL Post-installation steps](#).

Cygwin prerequisite installation

Previous versions of Sage targeted the Windows platform using Cygwin.

As of Sage 9.7, we no longer recommend attempting to build Sage on Cygwin and instead suggest that users on Windows 10 and 11 switch to installing Sage using Windows Subsystem for Linux (WSL), which gives a better performance and user/developer experience than Cygwin.

Users on hardware configurations that do not support running WSL, as well as users on legacy versions of Windows such as Windows 8 may find it necessary to build Sage on Cygwin.

Warning: As of Sage 9.7, [known issues with several packages](#) will prevent a successful installation. Users need to be prepared to contribute to Sage by fixing these issues.

Use the following instructions to get started.

1. Download [the 64-bit version of Cygwin](#) (do not get the 32-bit version; it is not supported by Sage).
2. Run the `setup-x86_64.exe` graphical installer. Pick the default options in most cases. At the package selection screen, use the search bar to find and select at least the following packages: `bzip2`, `coreutils`, `curl`, `gawk`, `gzip`, `tar`, `wget`, `git`.
3. Start the Cygwin terminal and ensure you get a working bash prompt.
4. Make sure the path of your Cygwin home directory does not contain space characters. Also avoid building in home directories of Windows domain users or in paths with capital letters.

By default, your username in Cygwin is the same as your username in Windows. This might contain spaces and other traditionally non-UNIX-friendly characters, e.g., if it is your full name. You can check this as follows:

```
$ whoami
Erik M. Bray
```

This means your default home directory on Cygwin contains this username verbatim; in the above example, `/home/Erik M. Bray`. It will save some potential trouble if you change your Cygwin home directory to contain only alphanumeric characters, for example, `/home/embray`. The easiest way to do this is to first create the home directory you want to use instead, then create an `/etc/passwd` file specifying that directory as your home, as follows:

```
$ whocanibe=embray
$ mkdir /home/$whocanibe
$ mkpasswd.exe -l -u "$(whoami)" | sed -r 's,/home/[^:]+,/home/'$whocanibe, > /etc/
->passwd
```

After this, close all Cygwin terminals (ensure nothing in `C:\cygwin64` is running), then start a new Cygwin terminal and your home directory should have moved.

There are [other ways to do this](#), but the above seems to be the simplest that's still supported.

5. (Optional) Although it is possible to install Sage's dependencies using the Cygwin graphical installer, it is recommended to install the `apt-cyg` command-line package installer, which is used for the remainder of these instructions. To install `apt-cyg`, run:

```
$ curl -OL https://rawgit.com/transcode-open/apt-cyg/master/apt-cyg
$ install apt-cyg /usr/local/bin
$ rm -f apt-cyg
```

6. Then, to install the current set of system packages known to work for building Sage, run the following command (or use the graphical installer to select and install these packages):

```
$ apt-cyg install binutils bzip2 cddlib-devel cddlib-tools cmake curl findutils_
->gcc-core gcc-fortran gcc-g++ gengetopt glpk info libatomic_ops-devel libboost-
->devel libbz2-devel libcrypt-devel libcurl-devel libffi-devel libflint-devel_
->libfreetype-devel libgc-devel libgd-devel libglpk-devel libgmp-devel libgsl-devel_
->libiconv-devel liblapack-devel liblzma-devel libmpc-devel libmpfr-devel_
->libncurses-devel libntnl-devel libopenblas libreadline-devel libsqlite3-devel_
->libssl-devel libsuitesparseconfig-devel libzmq-devel m4 make maxima ninja patch_
```

(continues on next page)

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```
↪perl perl-ExtUtils-MakeMaker python-pip-wheel python-setuptools-wheel python39_
↪python39-devel python39-urllib3 qhull singular singular-devel sqlite3 tar which_
↪xz zlib-devel
```

Optional packages that are also known to be installable via system packages include:

```
$ apt-cyg install R clang graphviz lib4ti2-devel lib4ti2_0 libisl-devel libtirpc-
↪devel libxml2-devel perl-Term-ReadLine-Gnu
```

Note: On Cygwin, at any point in time after building/installing software, it may be required to “rebase” dll files. Sage provides some scripts, located in `$SAGE_LOCAL/bin`, to do so:

- `sage-rebaseall.sh`, a shell script which calls Cygwin’s `rebaseall` program. It must be run within a dash shell from the `SAGE_ROOT` directory after all other Cygwin processes have been shut down and needs write-access to the system-wide rebase database located at `/etc/rebase.db.i386`, which usually means administrator privileges. It updates the system-wide database and adds Sage dlls to it, so that subsequent calls to `rebaseall` will take them into account.
- `sage-rebase.sh`, a shell script which calls Cygwin’s `rebase` program together with the `-O/--oblivious` option. It must be run within a shell from `SAGE_ROOT` directory. Contrary to the `sage-rebaseall.sh` script, it neither updates the system-wide database, nor adds Sage dlls to it. Therefore, subsequent calls to `rebaseall` will not take them into account.
- `sage-rebaseall.bat` (respectively `sage-rebase.bat`), an MS-DOS batch file which calls the `sage-rebaseall.sh` (respectively `sage-rebase.sh`) script. It must be run from a Windows command prompt, after adjusting `SAGE_ROOT` to the Windows location of Sage’s home directory, and, if Cygwin is installed in a non-standard location, adjusting `CYGWIN_ROOT` as well.

Some systems may encounter this problem frequently enough to make building or testing difficult. If executing the above scripts or directly calling `rebaseall` does not solve rebasing issues, deleting the system-wide database and then regenerating it from scratch, e.g., by executing `sage-rebaseall.sh`, might help.

Other platforms

On Solaris, you would use `pkgadd` and on OpenSolaris `ipf` to install the necessary software.

On other systems, check the documentation for your particular operating system.

Notes on using conda

If you don’t want conda to be used by sage, deactivate conda (for the current shell session).

- Type:

```
$ conda deactivate
```

- Repeat the command until `conda info` shows:

```
$ conda info

active environment : None
...
```

Then SageMath will be built either using the compilers provided by the operating system, or its own compilers.

4.4.2 Additional software

Recommended programs

The following programs are recommended. They are not strictly required at build time or at run time, but provide additional capabilities:

- **dvipng**.
- **ffmpeg**.
- **ImageMagick**.
- **LaTeX**: highly recommended.

It is highly recommended that you have [LaTeX](#) installed, but it is not required. The most popular packaging is [TeX Live](#), which can be installed following the directions on their web site. On Linux systems you can alternatively install your distribution's texlive packages:

```
$ sudo apt-get install texlive      # debian
$ sudo yum install texlive         # redhat
```

or similar commands. In addition to the base TeX Live install, you may need some optional TeX Live packages, for example country-specific babel packages for the localized Sage documentation.

If you don't have either ImageMagick or ffmpeg, you won't be able to view animations. ffmpeg can produce animations in more different formats than ImageMagick, and seems to be faster than ImageMagick when creating animated GIFs. Either ImageMagick or dvipng is used for displaying some LaTeX output in the Sage notebook.

On Debian/Ubuntu, the following system packages are recommended.

- `texlive-generic-extra` (to generate pdf documentation)
- `texlive-xetex` (to convert Jupyter notebooks to pdf)
- `latexmk` (to generate pdf documentation)
- `pandoc` (to convert Jupyter notebooks to pdf)
- `dvipng` (to render text with LaTeX in Matplotlib)
- `default-jdk` (to run the Jmol 3D viewer from the console and generate images for 3D plots in the documentation)
- `ffmpeg` (to produce animations)
- `libavdevice-dev` (to produce animations)

Tcl/Tk

If you want to use Tcl/Tk libraries in Sage, you need to install the Tcl/Tk and its development headers before building Sage. Sage's Python will then automatically recognize your system's install of Tcl/Tk.

On Linux systems, these are usually provided by the **tk** and **tk-dev** (or **tk-devel**) packages which can be installed using:

```
$ sudo apt-get install tk tk-dev
```

or similar commands.

If you installed Sage first, all is not lost. You just need to rebuild Sage's Python and any part of Sage relying on it:

```
$ sage -f python3 # rebuild Python3
$ make           # rebuild components of Sage depending on Python
```

after installing the Tcl/Tk development libraries as above.

If

```
sage: import _tkinter
sage: import Tkinter
```

does not raise an `ImportError`, then it worked.

4.4.3 Step-by-step installation procedure

General procedure

1. Follow the procedure in the file `README.md` in `SAGE_ROOT`.
2. Additional remarks: You do not need to be logged in as root, since no files are changed outside of the `sage-x.y` directory. In fact, **it is inadvisable to build Sage as root**, as the root account should only be used when absolutely necessary and mistyped commands can have serious consequences if you are logged in as root.

Typing `make` performs the usual steps for each Sage's dependency, but installs all the resulting files into the installation prefix. Depending on the age and the architecture of your system, it can take from a few tens of minutes to several hours to build Sage from source. On really slow hardware, it can even take a few days to build Sage.

Each component of Sage has its own build log, saved in `SAGE_ROOT/logs/pkgs`. If the build of Sage fails, you will see a message mentioning which package(s) failed to build and the location of the log file for each failed package. If this happens, then paste the contents of these log file(s) to the Sage support newsgroup at <https://groups.google.com/group/sage-support>. If the log files are very large (and many are), then don't paste the whole file, but make sure to include any error messages. It would also be helpful to include the type of operating system (Linux, macOS, Solaris, OpenSolaris, Cygwin, or any other system), the version and release date of that operating system and the version of the copy of Sage you are using. (There are no formal requirements for bug reports – just send them; we appreciate everything.)

See *Make targets* for some targets for the `make` command and *Environment variables* for additional information on useful environment variables used by Sage.

3. To start Sage, you can now simply type from Sage's home directory:

```
$ ./sage
```

You should see the Sage prompt, which will look something like this:

```
$ sage
+-----+
| SageMath version 8.8, Release Date: 2019-06-26           |
| Using Python 3.10.4. Type "help()" for help.             |
+-----+
sage:
```

Note that Sage should take well under a minute when it starts for the first time, but can take several minutes if the file system is slow or busy. Since Sage opens a lot of files, it is preferable to install Sage on a fast filesystem if possible.

Just starting successfully tests that many of the components built correctly. Note that this should have been already automatically tested during the build process. If the above is not displayed (e.g., if you get a massive traceback), please report the problem, e.g., at <https://groups.google.com/group/sage-support>.

After Sage has started, try a simple command:

```
sage: 2 + 2
4
```

Or something slightly more complicated:

```
sage: factor(2005)
5 * 401
```

- Optional, but highly recommended: Test the install by typing `./sage --testall`. This runs most examples in the source code and makes sure that they run exactly as claimed. To test all examples, use `./sage --testall --optional=all --long`; this will run examples that take a long time, and those that depend on optional packages and software, e.g., Mathematica or Magma. Some (optional) examples will therefore likely fail.

Alternatively, from within `$$SAGE_ROOT`, you can type `make test` (respectively `make ptest`) to run all the standard test code serially (respectively in parallel).

Testing the Sage library can take from half an hour to several hours, depending on your hardware. On slow hardware building and testing Sage can even take several days!

- Optional: Check the interfaces to any other software that you have available. Note that each interface calls its corresponding program by a particular name: **Mathematica** is invoked by calling `math`, **Maple** by calling `maple`, etc. The easiest way to change this name or perform other customizations is to create a redirection script in `$$SAGE_ROOT/local/bin`. Sage inserts this directory at the front of your `PATH`, so your script may need to use an absolute path to avoid calling itself; also, your script should pass along all of its arguments. For example, a maple script might look like:

```
#!/bin/sh

exec /etc/maple10.2/maple.tty "$@"
```

- Optional: There are different possibilities to make using Sage a little easier:

- Make a symbolic link from `/usr/local/bin/sage` (or another directory in your `PATH`) to `$$SAGE_ROOT/sage`:

```
$ ln -s /path/to/sage-x.y/sage /usr/local/bin/sage
```

Now simply typing `sage` from any directory should be sufficient to run Sage.

- Copy `$$SAGE_ROOT/sage` to a location in your `PATH`. If you do this, make sure you edit the line:

```
#SAGE_ROOT=/path/to/sage-version
```

at the beginning of the copied sage script according to the direction given there to something like:

```
SAGE_ROOT=<SAGE_ROOT>
```

(note that you have to change <SAGE_ROOT> above!). It is best to edit only the copy, not the original.

- For KDE users, create a bash script called `sage` containing the lines (note that you have to change <SAGE_ROOT> below!):

```
#!/usr/bin/env bash  
  
konsole -T "sage" -e <SAGE_ROOT>/sage
```

make it executable:

```
$ chmod a+x sage
```

and put it somewhere in your PATH.

You can also make a KDE desktop icon with this line as the command (under the Application tab of the Properties of the icon, which you get my right clicking the mouse on the icon).

- On Linux and macOS systems, you can make an alias to `$SAGE_ROOT/sage`. For example, put something similar to the following line in your `.bashrc` file:

```
alias sage=<SAGE_ROOT>/sage
```

(Note that you have to change <SAGE_ROOT> above!) Having done so, quit your terminal emulator and restart it. Now typing `sage` within your terminal emulator should start Sage.

7. Optional: Install optional Sage packages and databases. See [the list of optional packages in the reference manual](#) for detailed information, or type `sage --optional` (this requires an Internet connection).

Then type `sage -i <package-name>` to automatically download and install a given package.

8. Have fun! Discover some amazing conjectures!

4.4.4 Make targets

To build Sage from scratch, you would typically execute `make` in Sage's home directory to build Sage and its [HTML](#) documentation. The `make` command is pretty smart, so if your build of Sage is interrupted, then running `make` again should cause it to pick up where it left off. The `make` command can also be given options, which control what is built and how it is built:

- `make build` builds Sage: it compiles all of the Sage packages. It does not build the documentation.
- `make doc` builds Sage's documentation in HTML format. Note that this requires that Sage be built first, so it will automatically run `make build` first. Thus, running `make doc` is equivalent to running `make`.
- `make doc-pdf` builds Sage's documentation in PDF format. This also requires that Sage be built first, so it will automatically run `make build`.
- `make doc-html-no-plot` builds Sage's documentation in html format but skips the inclusion of graphics auto-generated using the `.. PLOT` markup and the `sphinx_plot` function. This is primarily intended for use when producing certain binary distributions of Sage, to lower the size of the distribution. As of this writing (December 2014, Sage 6.5), there are only a few such plots, adding about 4M to the `local/share/doc/sage/` directory.

In the future, this may grow, of course. Note: after using this, if you want to build the documentation and include the pictures, you should run `make doc-uninstall`, because the presence, or lack, of pictures is cached in the documentation output. You can benefit from this no-plot feature with other make targets by doing `export SAGE_DOCBUILD_OPTS+=' --no-plot'`

- `make ptest` and `make ptestlong`: these run Sage’s test suite. The first version skips tests that need more than a few seconds to complete and those which depend on optional packages or additional software. The second version includes the former, and so it takes longer. The “p” in `ptest` stands for “parallel”: tests are run in parallel. If you want to run tests serially, you can use `make test` or `make testlong` instead. If you want to run tests depending on optional packages and additional software, you can use `make testall`, `make ptestall`, `make testalllong`, or `make ptestalllong`.
- `make doc-uninstall` and `make doc-clean` each remove several directories which are produced when building the documentation.
- `make distclean` restores the Sage directory to its state before doing any building: it is almost equivalent to deleting Sage’s entire home directory and unpacking the source tarfile again, the only difference being that the `.git` directory is preserved, so git branches are not deleted.

4.4.5 Environment variables

Sage uses several environment variables to control its build process. Most users won’t need to set any of these: the build process just works on many platforms. (Note though that setting `MAKE`, as described below, can significantly speed up the process.) Building Sage involves building about 100 packages, each of which has its own compilation instructions.

The Sage source tarball already includes the sources for all standard packages, that is, it allows you to build Sage without internet connection. The git repository, however, does not contain the source code for third-party packages. Instead, it will be downloaded as needed (Note: you can run `make download` to force downloading packages before building). Package downloads use the Sage mirror network, the nearest mirror will be determined automatically for you. This is influenced by the following environment variable:

- `SAGE_SERVER` - Try the specified mirror first, before falling back to the official Sage mirror list. Note that Sage will search the directory
 - `SAGE_SERVER/spkg/upstream` for upstream tarballs.

Here are some of the more commonly used variables affecting the build process:

- `MAKE` - one useful setting for this variable when building Sage is `MAKE='make -jNUM'` to tell the make program to run `NUM` jobs in parallel when building. Note that some Sage packages may not support this variable.

Some people advise using more jobs than there are CPU cores, at least if the system is not heavily loaded and has plenty of RAM; for example, a good setting for `NUM` might be between 1 and 1.5 times the number of cores. In addition, the `-l` option sets a load limit: `MAKE='make -j4 -l5.5`, for example, tells make to try to use four jobs, but to not start more than one job if the system load average is above 5.5. See the manual page for GNU make: [Command-line options](#) and [Parallel building](#).

Warning: Some users on single-core macOS machines have reported problems when building Sage with `MAKE='make -jNUM'` with `NUM` greater than one.

- `SAGE_NUM_THREADS` - if set to a number, then when building the documentation, parallel doctesting, or running `sage -b`, use this many threads. If this is not set, then determine the number of threads using the value of the `MAKE` (see above) or `MAKEFLAGS` environment variables. If none of these specifies a number of jobs, use one thread (except for parallel testing: there we use a default of the number of CPU cores, with a maximum of 8 and a minimum of 2).

- `V` - if set to `0`, silence the build. Instead of showing a detailed compilation log, only one line of output is shown at the beginning and at the end of the installation of each Sage package. To see even less output, use:

```
$ make -s V=0
```

(Note that the above uses the syntax of setting a Makefile variable.)

- `SAGE_CHECK` - if set to `yes`, then during the build process, or when installing packages manually, run the test suite for each package which has one, and stop with an error if tests are failing. If set to `warn`, then only a warning is printed in this case. See also `SAGE_CHECK_PACKAGES`.
- `SAGE_CHECK_PACKAGES` - if `SAGE_CHECK` is set to `yes`, then the default behavior is to run test suites for all spkgs which contain them. If `SAGE_CHECK_PACKAGES` is set, it should be a comma-separated list of strings of the form `package-name` or `!package-name`. An entry `package-name` means to run the test suite for the named package regardless of the setting of `SAGE_CHECK`. An entry `!package-name` means to skip its test suite. So if this is set to `pp1, !python3`, then always run the test suite for PPL, but always skip the test suite for Python 3.

Note: As of Sage 9.1, the test suites for the Python 2 and 3 spkgs fail on most platforms. So when this variable is empty or unset, Sage uses a default of `!python2, !python3`.

- `SAGE_INSTALL_GCC` - **Obsolete, do not use, to be removed**
- `SAGE_INSTALL_CCACHE` - by default Sage doesn't install `ccache`, however by setting `SAGE_INSTALL_CCACHE=yes` Sage will install `ccache`. Because the Sage distribution is quite large, the maximum cache is set to 4G. This can be changed by running `sage -sh -c "ccache --max-size=SIZE"`, where `SIZE` is specified in gigabytes, megabytes, or kilobytes by appending a "G", "M", or "K".
Sage does not include the sources for `ccache` since it is an optional package. Because of this, it is necessary to have an Internet connection while building `ccache` for Sage, so that Sage can pull down the necessary sources.
- `SAGE_DEBUG` - controls debugging support. There are three different possible values:
 - Not set (or set to anything else than "yes" or "no"): build binaries with debugging symbols, but no special debug builds. This is the default. There is no performance impact, only additional disk space is used.
 - `SAGE_DEBUG=no`: no means no debugging symbols (that is, no `gcc -g`), which saves some disk space.
 - `SAGE_DEBUG=yes`: build debug versions if possible (in particular, Python is built with additional debugging turned on and Singular is built with a different memory manager). These will be notably slower but, for example, make it much easier to pinpoint memory allocation problems.

Instead of using `SAGE_DEBUG` one can configure with `--enable-debug={no|symbols|yes}`.

- `SAGE_PROFILE` - controls profiling support. If this is set to `yes`, profiling support is enabled where possible. Note that Python-level profiling is always available; This option enables profiling in Cython modules.
- `SAGE_SPKG_INSTALL_DOCS` - if set to `yes`, then install package-specific documentation to `$SAGE_ROOT/local/share/doc/PACKAGE_NAME/` when an spkg is installed. This option may not be supported by all spkgs. Some spkgs might also assume that certain programs are available on the system (for example, `latex` or `pdflatex`).
- `SAGE_DOCBUILD_OPTS` - the value of this variable is passed as an argument to `sage --docbuild all html` or `sage --docbuild all pdf` when you run `make`, `make doc`, or `make doc-pdf`. For example, you can add `--no-plot` to this variable to avoid building the graphics coming from the `.. PLOT` directive within the documentation, or you can add `--include-tests-blocks` to include all "TESTS" blocks in the reference manual. Run `sage --docbuild help` to see the full list of options.
- `SAGE_BUILD_DIR` - the default behavior is to build each spkg in a subdirectory of `$SAGE_ROOT/local/var/tmp/sage/build/`; for example, build version 7.27.0 of `ipython` in the directory `$SAGE_ROOT/local/var/tmp/sage/build/ipython-7.27.0/`. If this variable is set, then build in `$SAGE_BUILD_DIR/ipython-7.`

27.0/ instead. If the directory `$SAGE_BUILD_DIR` does not exist, it is created. As of this writing (Sage 4.8), when building the standard Sage packages, 1.5 gigabytes of free space are required in this directory (or more if `SAGE_KEEP_BUILT_SPKGS=yes` – see below); the exact amount of required space varies from platform to platform. For example, the block size of the file system will affect the amount of space used, since some spkgs contain many small files.

Warning: The variable `SAGE_BUILD_DIR` must be set to the full path name of either an existing directory for which the user has write permissions, or to the full path name of a nonexistent directory which the user has permission to create. The path name must contain **no spaces**.

- `SAGE_KEEP_BUILT_SPKGS` - the default behavior is to delete each build directory – the appropriate subdirectory of `$SAGE_ROOT/local/var/tmp/sage/build` or `$SAGE_BUILD_DIR` – after each spkg is successfully built, and to keep it if there were errors installing the spkg. Set this variable to `yes` to keep the subdirectory regardless. Furthermore, if you install an spkg for which there is already a corresponding subdirectory, for example left over from a previous build, then the default behavior is to delete that old subdirectory. If this variable is set to `yes`, then the old subdirectory is moved to `$SAGE_ROOT/local/var/tmp/sage/build/old/` (or `$SAGE_BUILD_DIR/old`), overwriting any already existing file or directory with the same name.

Note: After a full build of Sage (as of version 4.8), these subdirectories can take up to 6 gigabytes of storage, in total, depending on the platform and the block size of the file system. If you always set this variable to `yes`, it can take even more space: rebuilding every spkg would use double the amount of space, and any upgrades to spkgs would create still more directories, using still more space.

Note: In an existing Sage installation, running `sage -i -s <package-name>` or `sage -f -s <package-name>` installs the spkg `<package-name>` and keeps the corresponding build directory; thus setting `SAGE_KEEP_BUILT_SPKGS` to `yes` mimics this behavior when building Sage from scratch or when installing individual spkgs. So you can set this variable to `yes` instead of using the `-s` flag for `sage -i` and `sage -f`.

- `SAGE_FAT_BINARY` - to build binaries that will run on the widest range of target CPUs set this variable to `yes` before building Sage or configure with `--enable-fat-binary`. This does not make the binaries relocatable, it only avoids newer CPU instruction set extensions. For relocatable (=can be moved to a different directory) binaries, you must use <https://github.com/sagemath/binary-pkg>
- `SAGE_SUDO` - set this to `sudo -E` or to any other command prefix that is necessary to write into a installation hierarchy (`SAGE_LOCAL`) owned by root or another user. Note that this command needs to preserve environment variable settings (plain `sudo` does not).

Not all Sage packages currently support `SAGE_SUDO`.

Therefore this environment variable is most useful when a system administrator wishes to install an additional Sage package that supports `SAGE_SUDO`, into a root-owned installation hierarchy (`SAGE_LOCAL`).

Environment variables dealing with specific Sage packages:

- `SAGE_MATPLOTLIB_GUI` - if set to anything non-empty except `no`, then Sage will attempt to build the graphical backend when it builds the `matplotlib` package.
- `PARI_CONFIGURE` - use this to pass extra parameters to PARI's `Configure` script, for example to specify graphics support (which is disabled by default). See the file `build/pkgs/pari/spkg-install` for more information.
- `SAGE_TUNE_PARI`: If `yes`, enable PARI self-tuning. Note that this can be time-consuming. If you set this variable to “yes”, you will also see this: **WARNING: Tuning PARI/GP is unreliable. You may find your build of PARI fails, or PARI/GP does not work properly once built. We recommend to build this package with `SAGE_CHECK="yes"`.**

- `PARI_MAKEFLAGS`: The value of this variable is passed as an argument to the `$MAKE` command when compiling `PARI`.

Some standard environment variables which are used by Sage:

- `CC` - while some programs allow you to use this to specify your C compiler, **not every Sage package recognizes this**. If GCC is installed within Sage, `CC` is ignored and Sage's `gcc` is used instead.
- `CPP` - similarly, this will set the C preprocessor for some Sage packages, and similarly, using it is likely quite risky. If GCC is installed within Sage, `CPP` is ignored and Sage's `cpp` is used instead.
- `CXX` - similarly, this will set the C++ compiler for some Sage packages, and similarly, using it is likely quite risky. If GCC is installed within Sage, `CXX` is ignored and Sage's `g++` is used instead.
- `FC` - similarly, this will set the Fortran compiler. This is supported by all Sage packages which have Fortran code. However, for historical reasons, the value is hardcoded during the initial make and subsequent changes to `$FC` might be ignored (in which case, the original value will be used instead). If GCC is installed within Sage, `FC` is ignored and Sage's `gfortran` is used instead.
- `CFLAGS`, `CXXFLAGS` and `FCFLAGS` - the flags for the C compiler, the C++ compiler and the Fortran compiler, respectively. The same comments apply to these: setting them may cause problems, because they are not universally respected among the Sage packages. Note also that `export CFLAGS=""` does not have the same effect as `unset CFLAGS`. The latter is preferable.
- Similar comments apply to other compiler and linker flags like `CPPFLAGS`, `LDFLAGS`, `CXXFLAG64`, `LDFLAG64`, and `LD`.
- `OPENBLAS_CONFIGURE` - adds additional configuration flags for the OpenBLAS package that gets added to the make command. (see [github issue #23272](#))

Variables dealing with doctesting:

- `SAGE_TIMEOUT` - used for Sage's doctesting: the number of seconds to allow a doctest before timing it out. If this isn't set, the default is 300 seconds (5 minutes).
- `SAGE_TIMEOUT_LONG` - used for Sage's doctesting: the number of seconds to allow a doctest before timing it out, if tests are run using `sage -t --long`. If this isn't set, the default is 1800 seconds (30 minutes).
- `SAGE_TEST_GLOBAL_ITER`, `SAGE_TEST_ITER`: these can be used instead of passing the flags `--global-iterations` and `--file-iterations`, respectively, to `sage -t`. Indeed, these variables are only used if the flags are unset. Run `sage -t -h` for more information on the effects of these flags (and therefore these variables).

Sage sets some other environment variables. The most accurate way to see what Sage does is to first run `env` from a shell prompt to see what environment variables you have set. Then run `sage --sh -c env` to see the list after Sage sets its variables. (This runs a separate shell, executes the shell command `env`, and then exits that shell, so after running this, your settings will be restored.) Alternatively, you can peruse the shell script `src/bin/sage-env`.

Sage also has some environment-like settings. Some of these correspond to actual environment variables while others have names like environment variables but are only available while Sage is running. To see a list, execute `sage .env`. [TAB] while running Sage.

4.4.6 Installation in a Multiuser Environment

This section addresses the question of how a system administrator can install a single copy of Sage in a multi-user computer network.

1. Using `sudo`, create the installation directory, for example, `/opt/sage/sage-x.y`. We refer to it as `SAGE_LOCAL` in the instructions below. Do not try to install into a directory that already contains other software, such as `/usr/local`:

```
$ sudo mkdir -p SAGE_LOCAL
```

2. Make the directory writable for you and readable by everyone:

```
$ sudo chown $(id -un) SAGE_LOCAL
$ sudo chmod 755 SAGE_LOCAL
```

3. Build and install Sage, following the instructions in [README.md](#), using the `configure` option `--prefix=SAGE_LOCAL`.

Do not use `sudo` for this step; building Sage must be done using your normal user account.

4. Optionally, create a symbolic link to the installed `sage` script in a directory that is in the users' `PATH`, for example `/usr/local/bin`:

```
$ sudo ln -s SAGE_LOCAL/bin/sage /usr/local/bin/sage
```

5. Optionally, change permissions to prevent accidental changes to the installation by yourself:

```
$ sudo chown -R root SAGE_LOCAL
```

This page was last updated in September 2022 (Sage 9.8).

4.5 Launching SageMath

Now we assume that you installed SageMath properly on your system. This section quickly explains how to start the Sage console and the Jupyter Notebook from the command line.

If you did install the Windows version or the macOS application you should have icons available on your desktops or launching menus. Otherwise you are strongly advised to create shortcuts for Sage as indicated at the end of the “Linux” Section in *Install from Pre-built Binaries*. Assuming that you have this shortcut, running

```
sage
```

in a console starts a Sage session. To quit the session enter `quit` and then press `<Enter>`.

To start a Jupyter Notebook instead of a Sage console, run the command

```
sage -n jupyter
```

instead of just `sage`. To quit the Jupyter Notebook press `<Ctrl> + <c>` twice in the console where you launched the command.

You can pass extra parameters to this command. For example,

```
sage -n jupyter --port 8899
```

will run the Jupyter server on a port different from the default (8888). In particular on WSL, this is very useful because Jupyter may not be able to detect whether the default port is already taken by another instance of Jupyter running in Windows.

4.5.1 Environment variables

Sage uses the following environment variables when it runs:

- `DOT_SAGE` - this is the directory, to which the user has read and write access, where Sage stores a number of files. The default location is `$HOME/.sage/`.
- `SAGE_STARTUP_FILE` - a file including commands to be executed every time Sage starts. The default value is `$DOT_SAGE/init.sage`.
- `BROWSER` - on most platforms, Sage will detect the command to run a web browser, but if this doesn't seem to work on your machine, set this variable to the appropriate command.
- `TMPDIR` - this variable is used by Python, and hence by Sage; it gives the directory in which temporary files should be stored. This includes files used by the notebook. Some browsers have security settings which restrict the locations of files that they will access, and users may need to set this variable to handle this situation.
- See <https://docs.python.org/3/using/cmdline.html#environment-variables> for more variables used by Python (not an exhaustive list). With Python 3.11 or later, a brief summary can also be obtained by running `python3 --help - env`.

4.5.2 Using a Jupyter Notebook remotely

If Sage is installed on a remote machine to which you have `ssh` access, you can launch a Jupyter Notebook using a command such as

```
ssh -L localhost:8888:localhost:8888 -t USER@REMOTE sage -n jupyter --no-browser --  
↪port=8888
```

where `USER@REMOTE` needs to be replaced by the login details to the remote machine. This uses local port forwarding to connect your local machine to the remote one. The command will print a URL to the console which you can copy and paste in a web browser.

Note that this assumes that a firewall which might be present between server and client allows connections on port 8888. See details on port forwarding on the internet, e.g. <https://www.ssh.com/ssh/tunneling/example>.

4.5.3 WSL Post-installation steps

If you've installed SageMath from source on WSL, there are a couple of extra steps you can do to make your life easier:

Create a notebook launch script

If you plan to use JupyterLab, install that first.

Now create a script called `~/sage_nb.sh` containing the following lines, and fill in the correct paths for your desired starting directory and `SAGE_ROOT`

```
#!/bin/bash
# Switch to desired windows directory
cd /mnt/c/path/to/desired/starting/directory
# Start the Jupyter notebook
SAGE_ROOT/sage --notebook
# Alternatively you can run JupyterLab - delete the line above, and uncomment the line
↪ below
#SAGE_ROOT/sage --notebook jupyterlab
```

Make it executable:

```
chmod ug+x ~/sage_nb.sh
```

Run it to test:

```
cd ~
./sage_nb.sh
```

The Jupyter(Lab) server should start in the terminal window, and your windows browser should open a page showing the Jupyter or JupyterLab starting page, at the directory you specified.

Create a shortcut

This is a final nicety that lets you start the Jupyter or JupyterLab server in one click:

- Open Windows explorer, and type %APPDATA%\Microsoft\Windows\Start Menu\Programs in the address bar and press enter. This is the folder that contains your start menu shortcuts. If you want the sage shortcut somewhere else (like your desktop), open that folder instead.
- Open a separate window and go to %LOCALAPPDATA%\Microsoft\WindowsApps\
- Right-click-drag the ubuntu.exe icon from the second window into the first, then choose Create shortcuts here from the context menu when you drop it.
- To customize this shortcut, right-click on it and choose properties.
 - On the General tab:
 - * Change the name to whatever you want, e.g. “Sage 9.2 JupyterLab”
 - On the Shortcut tab:
 - * Change Target to: ubuntu.exe run ~/sage_nb.sh
 - * Change Start in to: %USERPROFILE%
 - * Change Run to: Minimised
 - * Change the icon if you want

Now hit the start button or key and type the name you gave it. It should appear in the list, and should load the server and fire up your browser when you click on it.

For further reading you can have a look at the other documents in the SageMath documentation at <http://doc.sagemath.org/>.

4.5.4 Setting up SageMath as a Jupyter kernel in an existing Jupyter notebook or JupyterLab installation

You may already have a global installation of Jupyter. For added convenience, it is possible to link your installation of SageMath into your Jupyter installation, adding it to the list of available kernels that can be selected in the notebook or JupyterLab interface.

Assuming that SageMath can be invoked by typing `sage`, you can use

```
sage -sh -c 'ls -d $SAGE_VENV/share/jupyter/kernels/sagemath'
```

to find the location of the SageMath kernel description.

Now pick a name for the kernel that identifies it clearly and uniquely.

For example, if you install Sage from source tarballs, you could decide to include the version number in the name, such as `sagemath-9.6`. If you build SageMath from a clone of the git repository, it is better to choose a name that identifies the directory, perhaps `sagemath-dev` or `sagemath-teaching` because the version will change.

Now assuming that the Jupyter notebook can be started by typing `jupyter notebook`, the following command will install SageMath as a new kernel named `sagemath-dev`.

```
jupyter kernelspec install --user $(sage -sh -c 'ls -d $SAGE_VENV/share/jupyter/kernels/
↪sagemath') --name sagemath-dev
```

The `jupyter kernelspec` approach by default does lead to about 2Gb of SageMath documentation being copied into your personal jupyter configuration directory. You can avoid that by instead putting a symlink in the relevant spot. and

```
jupyter --paths
```

to find valid data directories for your Jupyter installation. A command along the lines of

```
ln -s $(sage -sh -c 'ls -d $SAGE_VENV/share/jupyter/kernels/sagemath') $HOME/.local/
↪share/jupyter/kernels/sagemath-dev
```

can then be used to create a symlink to the SageMath kernel description in a location where your own `jupyter` can find it.

If you have installed SageMath from source, the alternative command

```
ln -s $(sage -sh -c 'ls -d $SAGE_ROOT/venv/share/jupyter/kernels/sagemath') $HOME/.local/
↪share/jupyter/kernels/sagemath-dev
```

creates a symlink that will stay current even if you switch to a different Python version later.

To get the full functionality of the SageMath kernel in your global Jupyter installation, the following Notebook Extension packages also need to be installed (or linked) in the environment from which the Jupyter installation runs.

You can check the presence of some of these packages using the command `jupyter nbextension list`.

- For the Sage interacts, you will need the package `widgetsnbextension` installed in the Python environment of the Jupyter installation. If your Jupyter installation is coming from the system package manager, it is best to install `widgetsnbextension` in the same way. Otherwise, install it using `pip`.

To verify that interacts work correctly, you can evaluate the following code in the notebook:

```
@interact
def _(k=slider(vmin=-1.0, vmax= 3.0, step_size=0.1, default=0), auto_update=True):
```

(continues on next page)

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```
plot([lambda u:u^2-1, lambda u:u+k], (-2,2),
      ymin=-1, ymax=3, fill={1:[0]}, fillalpha=0.5).show()
```

- For 3D graphics using Three.js, by default, internet connectivity is needed, as SageMath’s custom build of the Javascript package Three.js is retrieved from a content delivery network.

To verify that online 3D graphics with Three.js works correctly, you can evaluate the following code in the notebook:

```
plot3d(lambda u,v:(u^2+v^2)/4-2, (-2,2), (-2,2)).show()
```

However, it is possible to configure graphics with Three.js for offline use. In this case, the Three.js installation from the Sage distribution needs to be made available in the environment of the Jupyter installation. This can be done by copying or symlinking. The Three.js installation in the environment of the Jupyter installation must exactly match the version that comes from the Sage distribution. It is not supported to use several Jupyter kernels corresponding to different versions of the Sage distribution.

To verify that offline 3D graphics with Three.js works correctly, you can evaluate the following code in the notebook:

```
plot3d(lambda u,v:(u^2+v^2)/4-2, (-2,2), (-2,2), online=False).show()
```

- For 3D graphics using jsmol, you will need the package `jupyter-ismol` installed in the Python environment of the Jupyter installation. You can install it using `pip`. (Alternatively, you can copy or symlink it.)

To verify that jsmol graphics work correctly, you can evaluate the following code in the notebook:

```
plot3d(lambda u,v:(u^2+v^2)/4-2, (-2,2), (-2,2)).show(viewer="jsmol")
```

Using Jupyter notebook through Visual Studio Code (VS Code) in WSL

If you have installed Sage on Windows using Windows Subsystem for Linux (WSL), it is convenient to use Visual Studio Code (VS Code) to interact with Sage.

Here are steps to use SageMath in a Jupyter notebook in VS Code:

- Install and run [VS Code](#) in Windows.
- Click the “Extension” icon on the left (or press `Ctrl + Shift + X`) to open a list of extensions. Install the “Remote - WSL” and “Jupyter” extensions.
- In the command palette (`Ctrl + Shift + P`), enter “Remote-WSL: New Window”, and hit `Enter`.
- In the command palette, enter “Create: New Jupyter Notebook”, and hit `Enter`.
- Click “Select Kernel” on the right (or press `Ctrl + Alt + Enter`), select SageMath, and hit `Enter`.

4.6 Troubleshooting

If no binary version is available for your system, you can fallback to the *Install from Source Code* or use one of the alternatives proposed at the end of *Welcome to Sage Installation Guide*.

If you have any problems building or running Sage, please take a look at the Installation FAQ in the [Sage Release Tour](#) corresponding to the version that you are installing. It may offer version-specific installation help that has become available after the release was made and is therefore not covered by this manual.

Also please do not hesitate to ask for help in the [SageMath forum](#) or the sage-support mailing list at <https://groups.google.com/forum/#!forum/sage-support>.

Also note the following. Each separate component of Sage is contained in an SPKG; these are stored in `build/pkgs/`. As each one is built, a build log is stored in `logs/pkgs/`, so you can browse these to find error messages. If an SPKG fails to build, the whole build process will stop soon after, so check the most recent log files first, or run:

```
grep -li "^Error" logs/pkgs/*
```

from the top-level Sage directory to find log files with error messages in them. Send the file `config.log` as well as the log file(s) of the packages that have failed to build in their entirety to the sage-support mailing list at <https://groups.google.com/group/sage-support>; probably someone there will have some helpful suggestions.

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