Computational Mathematics with SageMath
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Lecture – 15
Introduction and Installation of SageMath

Welcome to this course on Computational Mathematics with SageMath. Henceforth, we will start using SageMath to explore various concepts in mathematics, but before let me give you a very brief Introduction to SageMath including Installation of SageMath in your system or using it online.

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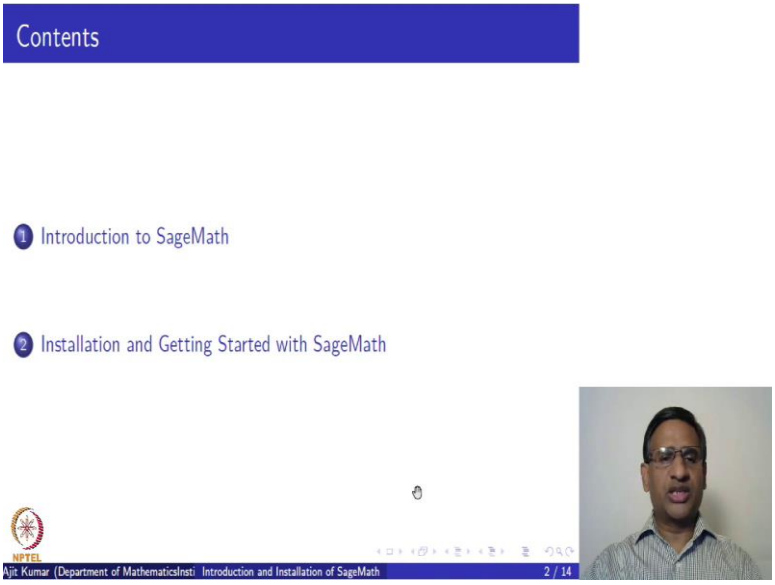

So, let us start. So, in this lecture, I am going to explain two things a very brief introduction to SageMath and then we will talk about installing SageMath and getting started with SageMath.

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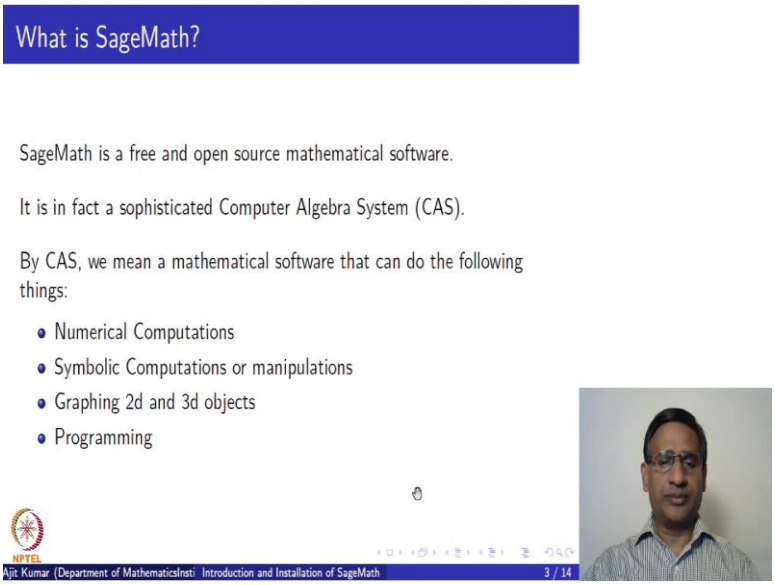

So, SageMath is a free and open source mathematical software. I am sure all of you understand meaning of free and open source. Open source means, you can not only use this software freely, but you can see the source code and not just that you can modify the source code and share it for academic purpose.

In fact, SageMath is a sophisticated Computer Algebra System CAS. By CAS, we mean a mathematical software that can do the following four things: it can do numerical computations; it can do symbolic manipulations that we use in mathematics all the time; it can do graphing of both 2d and 3d objects and you can write your own program.

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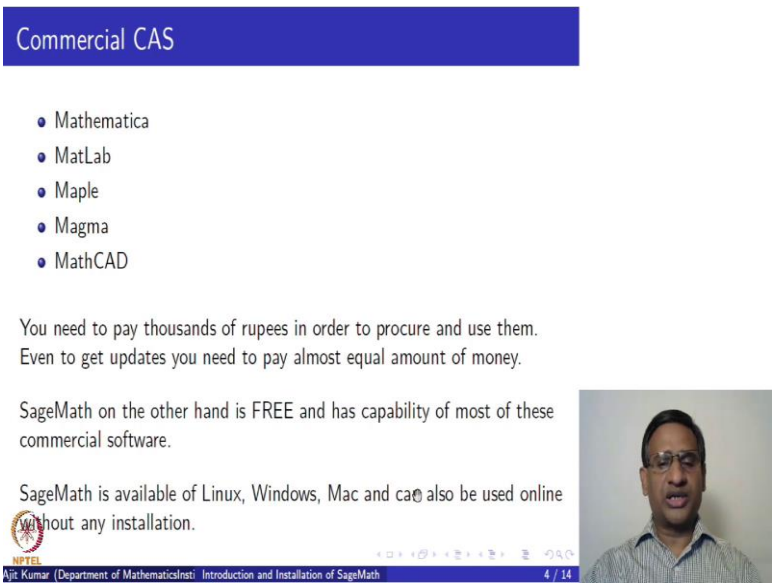

Most of you must have seen these computer algebra systems like Mathematica, MatLab, Maple, Magma, MathCAD – they are all commercial softwares. They require thousands of rupees in order to procure and use. Even to get updates you need to pay almost equal amount of money.

However, SageMath is FREE and it has all the capabilities of all these commercial software. And, it is available in all these standard operating systems like Linux, Windows, Mac and you can also use it online without installing it in your system.

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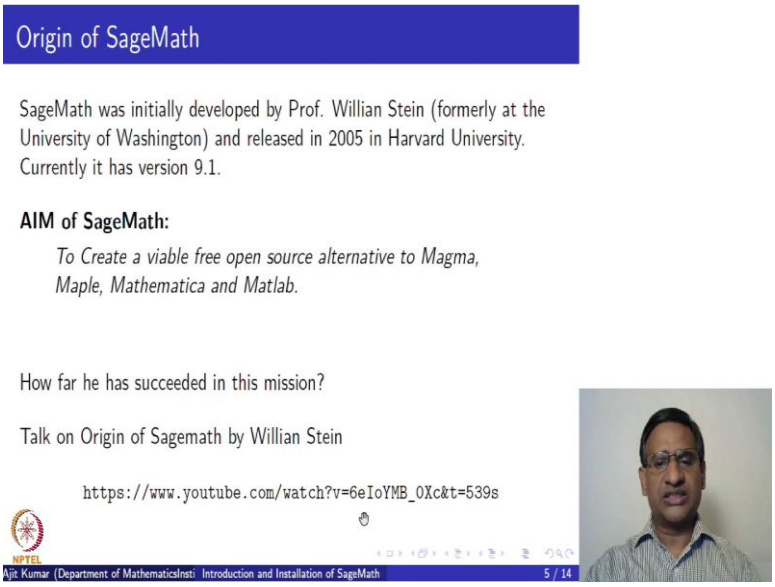

Sagemath was initially developed by Professor William Stein who was at that time Professor at University of Washington and the first version of it was released in 2005 in Harvard University. Currently Sage has 9.1 version. The basic aim of creating this software was to create a viable free open source alternative to Magma, Maple, Mathematica and MatLab.

How far he has succeeded in his mission? That you can decide after using this software and maybe comparing it with other software. You can look at a talk on origin of SageMath by William Stein on this following website that is www.youtube.com and this is the link: https://www.youtube.com/watch?v=6eIoYMB_0Xc&t=539s%20. So, this is where he talks about what is the motivation behind starting this open source software known as SageMath.

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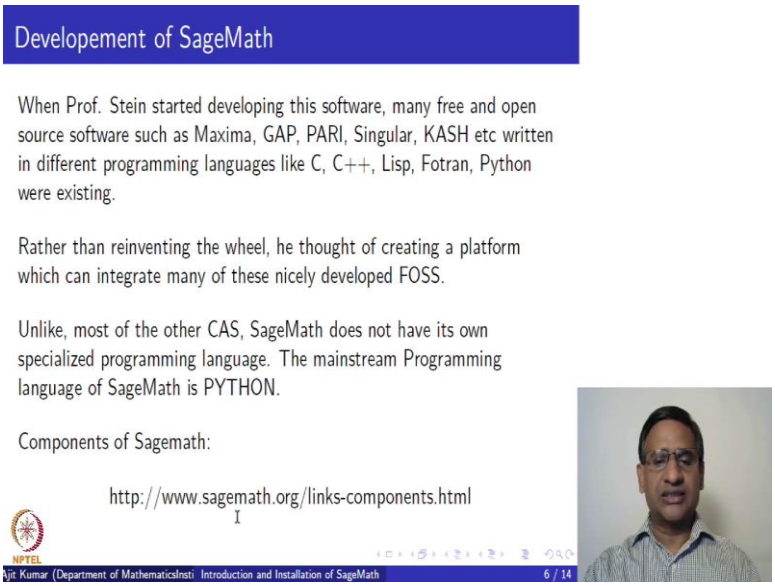

When Professor William Stein started developing this software at that time many free and open source software such as Maxima GAP, PARI, Singular, KASH etc were already available written in various programming languages like C, C++, Lisp, Fortran, Python etc. So, instead of reinventing the wheel he thought of creating a platform from which one can integrate all these free and open source software.

So, unlike most of the other computer algebra system, SageMath does not have its own specialized programming language. The mainstream programming language of SageMath is PYTHON. This is one reason why I introduced basics of python in first two weeks of this course, so that you can not only use SageMath, but you can use it effectively and you can write your own program also.

The SageMath has several components actually you can go to this particular website and see the components of SageMath, presently there are about 84 packages which constitute SageMath.

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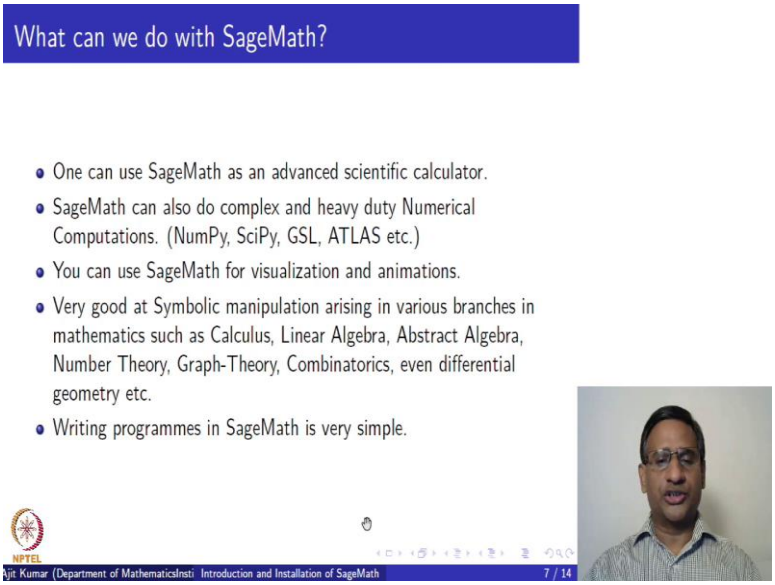

Now, what can we do with SageMath? So, one can use SageMath as an advanced scientific calculator. SageMath can also do complex and heavy-duty numerical computations and in background it uses NumPy, SciPy, GSL, ATLAS and various other numerical computational libraries.

You can use SageMath for visualizations for creating animations and it is very good at symbolic manipulations arising in various branches of mathematics such as Calculus, Linear Algebra, even Abstract Algebra, Number Theory, Graph Theory, Combinatorics, Differential Geometry and what not.

So, in fact, almost all branches of mathematics can be explored using SageMath. And, of course, you can write your own programs in SageMath and it is very simple. Any python program can be run as it is from SageMath worksheet.

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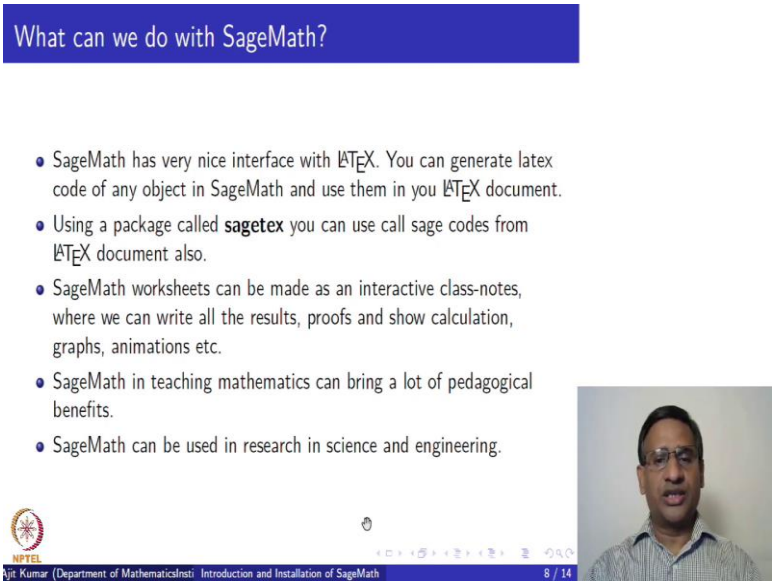

So, SageMath also has very nice interface with mathematical typesetting software known as LATEX. I am sure many of you must be aware of this software which has become a very popular mathematical and scientific typesetting tool. One can generate LATEX codes of any object in SageMath and you can use that code inside LATEX document.

Not only that there is a package called **sagetex** using which you can even call sage codes from LATEX document itself. SageMath worksheets can be made an interactive class-notes where one can write all the results, proofs and show calculations, graphs, animations and all these things in a single notebook.

It can be used as a teaching tool and it brings a lot of pedagogical benefits when teaching is concerned. SageMath can be used in research in science and engineering many people are using this in their research work.

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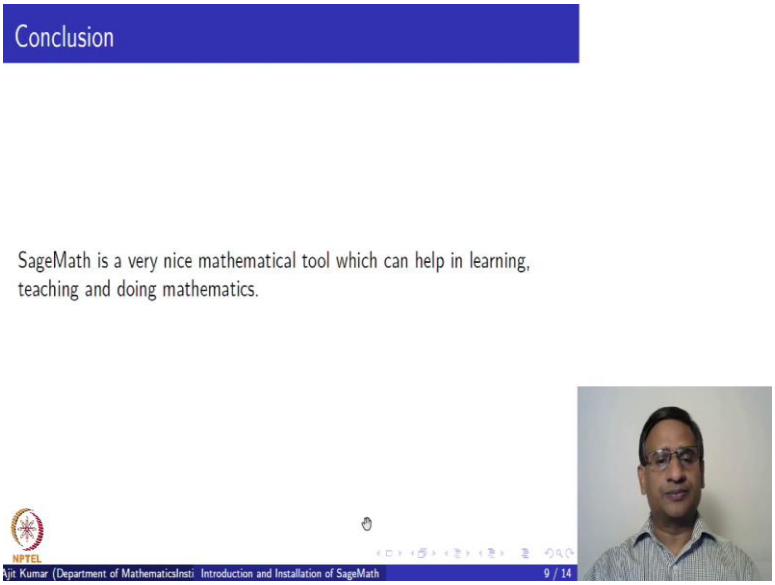

So, in conclusion, SageMath is a very nice mathematical tool which can help in learning mathematics, teaching mathematics, researching in mathematics and all the concepts in mathematics can be very easily explored using SageMath.

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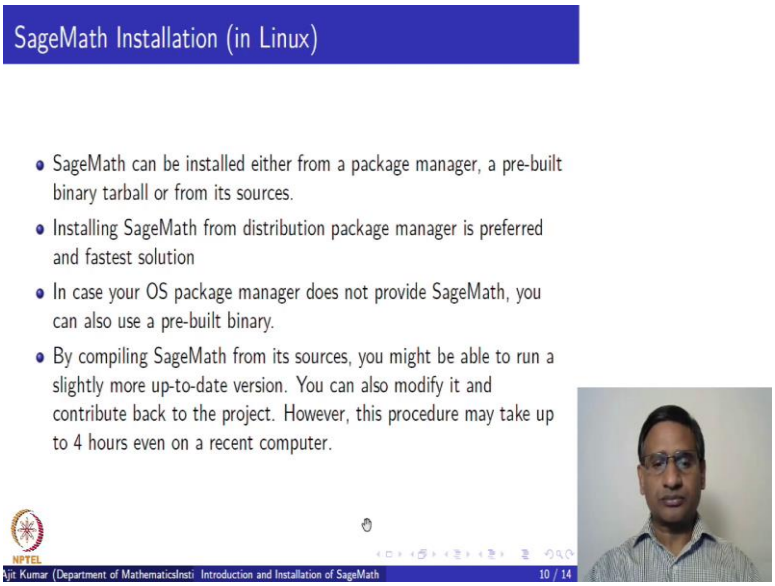

Now, next part we will explain how to install SageMath in various platforms. So, as I mentioned earlier SageMath is available in standard operating systems like Linux, Mac, Windows and it can also be used online. So, let me explain first how to install SageMath in Linux and then we will briefly explain on Mac and Windows.

So, installation of SageMath in Linux is fairly simple. One can install this either from package manager or from a pre-built binary tarball or from its source code. Installing SageMath from distribution package manager is preferred and it will be faster and it will take care of many of the dependency.

But, in case your package manager does not support or does not provide SageMath you can install from pre-built binary. You can compile SageMath from its source. However, it may be time consuming and it may take several hours in some cases. However, installing from the source code provides you some better facilities, you can have more update version and you can also use it for development.

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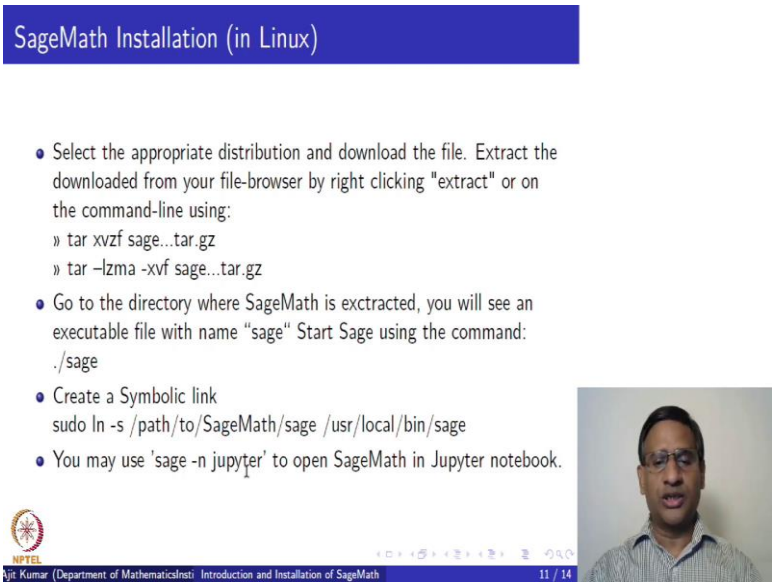

So, how do we install it in Linux? So, first you go to the SageMath official website which is sagemath.org. You can download the appropriate file and extract the downloaded file using either file-browser or by right clicking it. And, then you can also use command line to extract this tar file.

So, you can use >> tar xvzf sage…tar.gz (Note: sage…tar.gz is to be replaced by the exact file name which you have downloaded) or you can use >> tar -lzma -xvf sage…tar.gz again provide the file name which you have downloaded. Once you extract this it will extract in a folder called SageMath and in order to run SageMath you just go to that particular directory SageMath and then use the command: ./sage, this is an executive file and it will start SageMath.

If you want to run sage from anywhere in the terminal, you may create symbolic link using this: sudo ln -s /path_name_of_the_sage_executive_file /user/local/bin/sage. Then you can start Sage from anywhere.

You can also start SageMath in Jupyter notebook by using command ‘sage -n jupyter’. So, we have already seen using Python programming from Jupyter notebook and sage also runs from Jupyter notebook.

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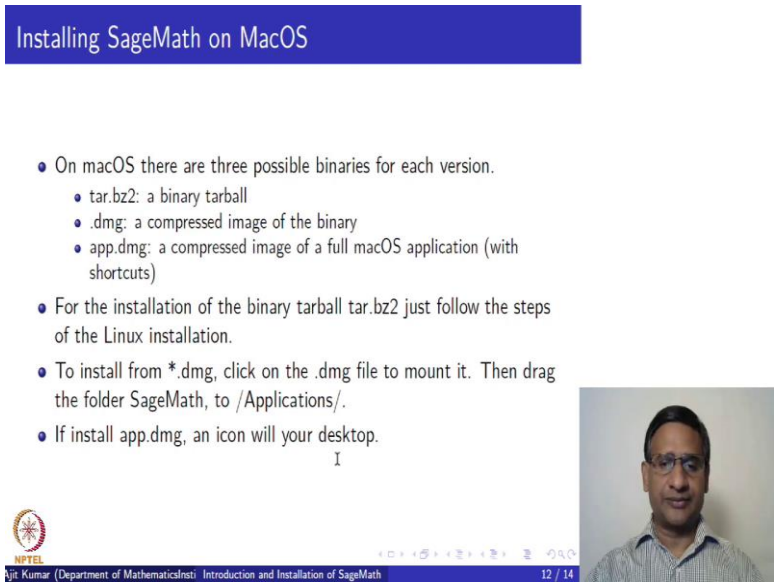

If you want to install SageMath on Mac operating system again it is possible and there are three possibilities. One can download binary tarball or you can download .dmg compressed image of the binary or you can also use app.dmg which is a compressed image of full Mac applications.

For installing SageMath using binary tarball the process is exactly similar to installing SageMath in Linux from tarball, but if you want to install from the dmg file you just double click it and then mount it and it will create folder called SageMath that you can drag it and put it inside these applications.

And, then you can go to the applications and then go to SageMath and then double click on the executive file. You can also install from app dot dmg. It will once you install, it will also create icons on your desktop, you can just double click and it will get started.

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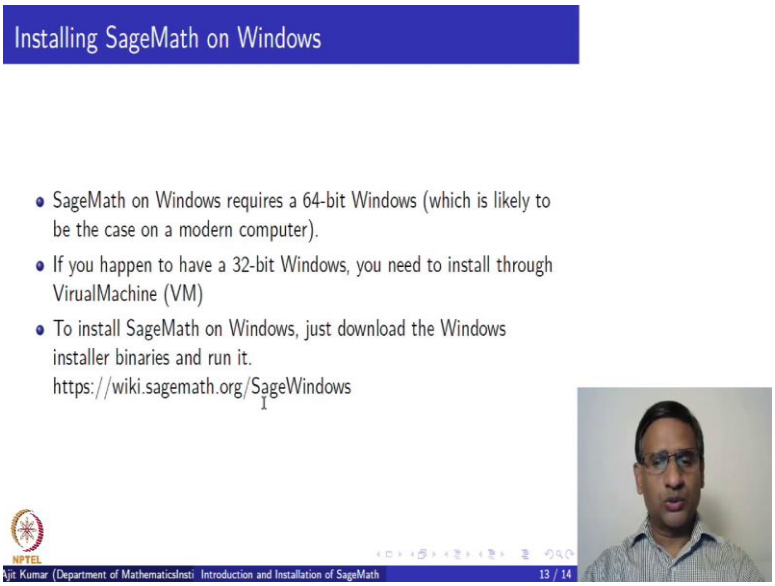

Now, if you want to install SageMath in Windows, I am pretty much sure that most of you must be using Window system. So, that is why I will also tell you how to install in Window system generally I prefer using from Linux system.

So, installation of SageMath in Windows require 64-bit Window system which is the most likely in most of the modern computers. Of course, you can also install in 32-bit Windows system, but the installation is through what is called Virtual Machine and it may be slightly inconvenient, but it is not difficult.

If you want to install SageMath on Windows system you can just download the executable or binary file which is installer binary file and just run it, it will install. You can go to this site https://wiki.sagemath.org/SageWindows – it will provide the step by step installation of SageMath in Windows.

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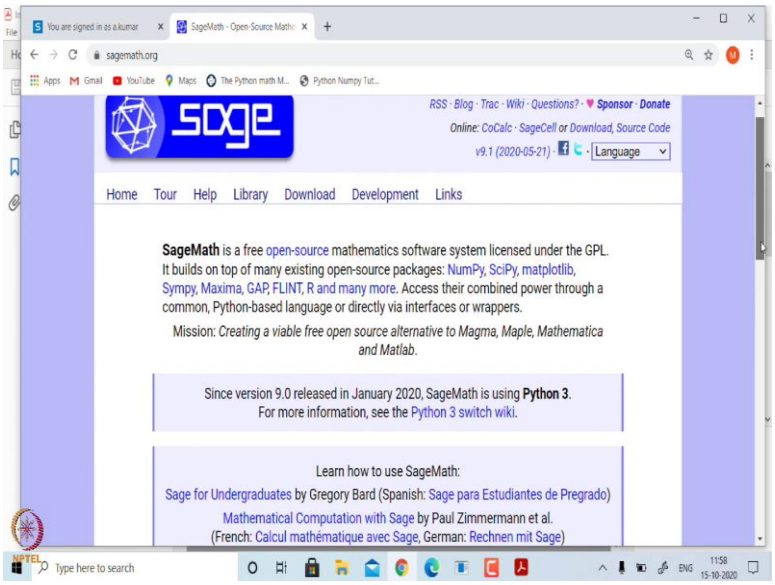

So, let me go to the website of SageMath. So, let us go to the official SageMath website. So, this is sagemath.org is it is official website and if you go through this website it tells you what is SageMath and it also tells you what are its components.

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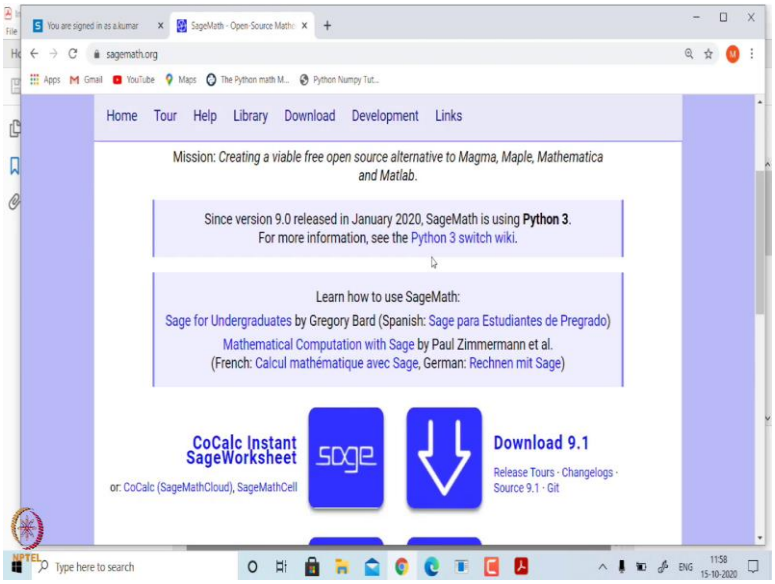

If you click here then it will tell you what are the components of this and it also provides you some online books which are freely available. For example, one of the book that Mathematical Computation with Sage by Paul Zimmermann this is very nice book and you can download by clicking on this.

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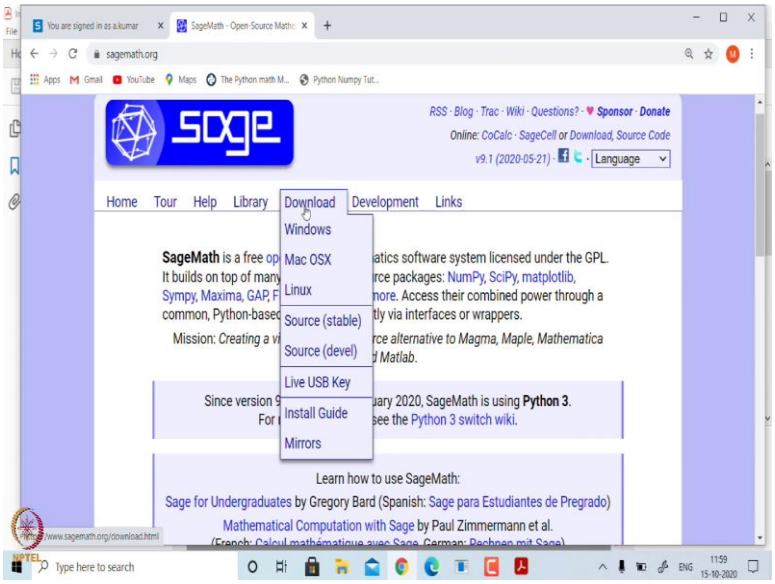

So, you can also click on this download and suppose you want to install in Windows system you click on here, if you want to install in Mac system you click here, if you want to install on Linux system you click here. You can also install SageMath using Live USB Key and of course, you can click on this installation guide.

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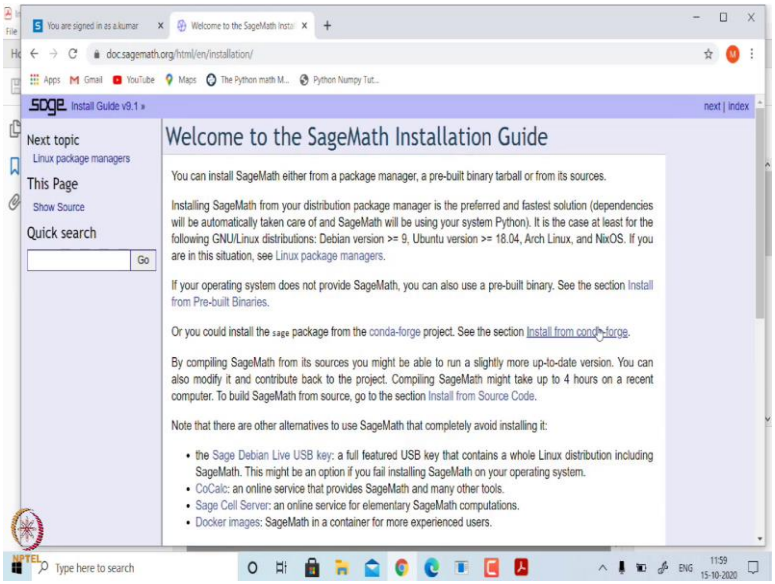

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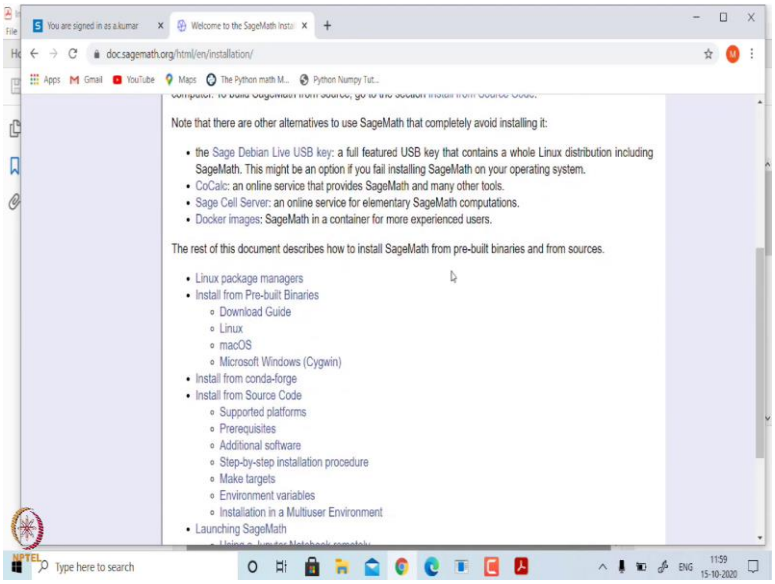

And, if you just go down here it will tell you step by step installation in various operating systems including Linux, Mac and Windows.

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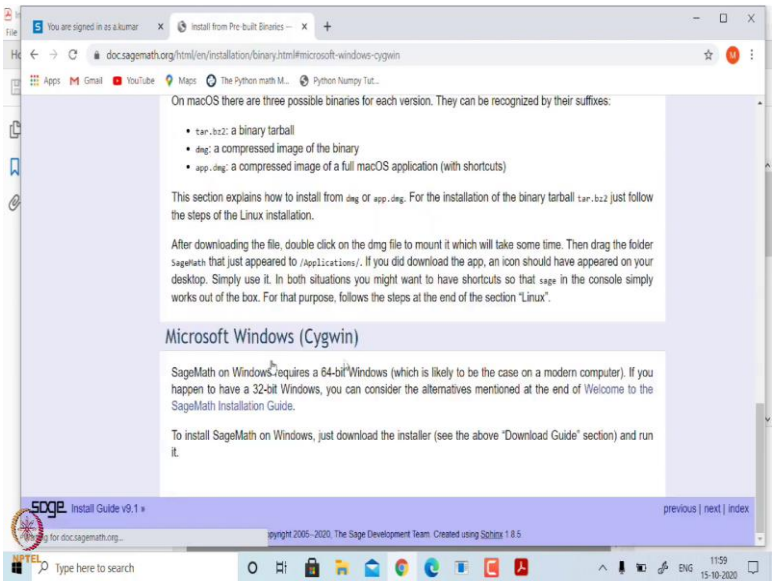

So, for example, if I click on Windows system, it will tell you where is this installation guide. So, let us click on this installation guide, it will tell you step by step installation.

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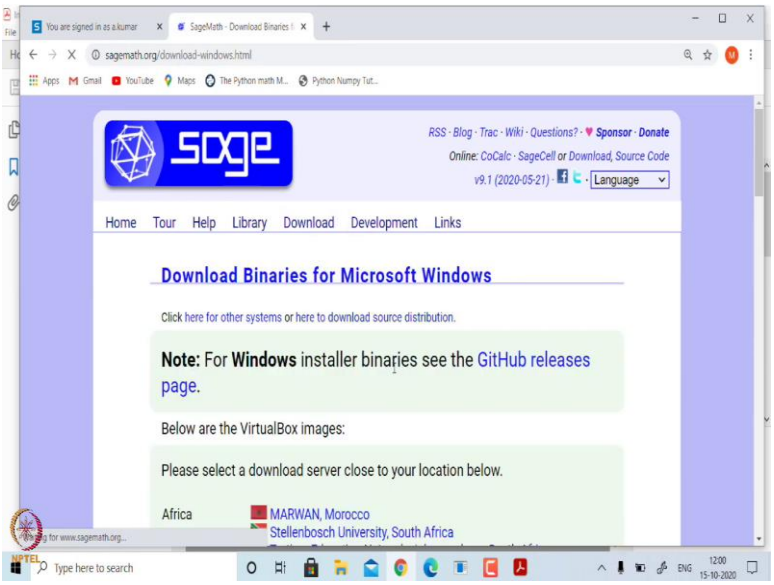

So, let me go to this website again i.e. sagemath.org and let us click on Download Windows and when you click on Download > Windows, then it tells you that for Windows installer binaries you can go to even GitHub release page or you can go to one of these mirror website.

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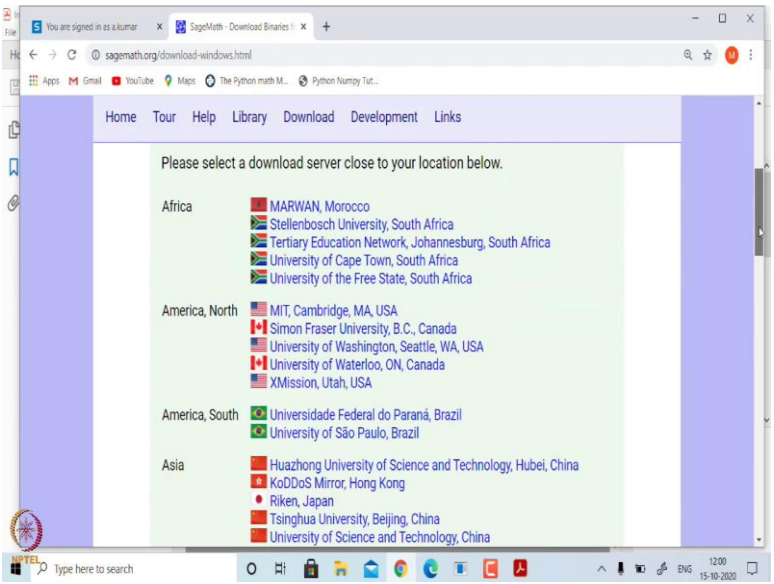

For example, if you click on MIT, Cambridge, MA, USA it will give you if you click on this and then it will take you to that mirror site.

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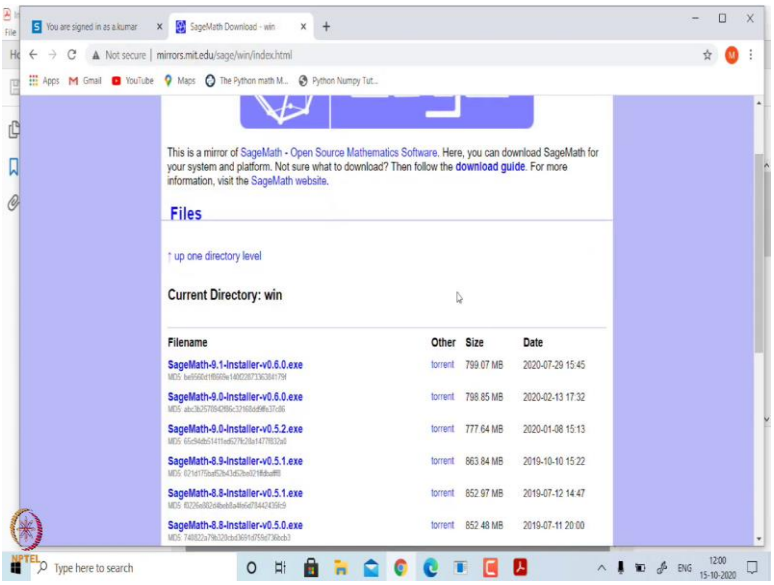

You can download the installer executable file and then start installing.

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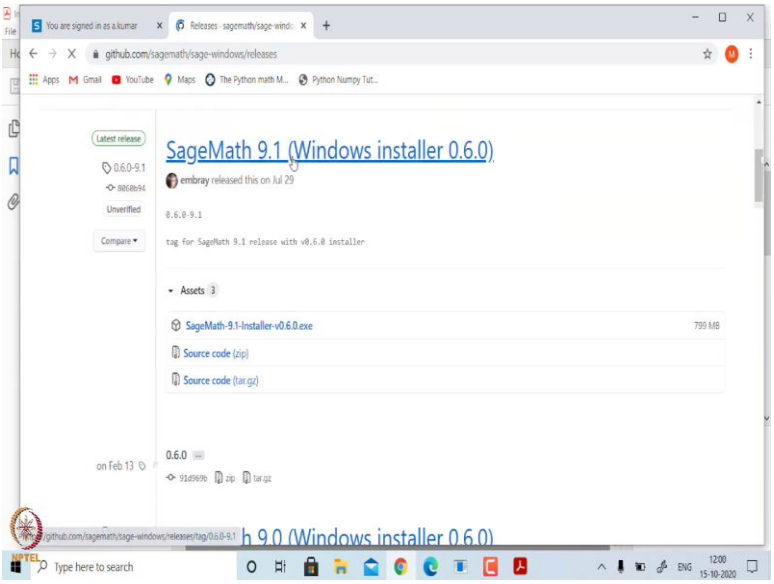

So, let me go to the GitHub site. So, when you go to GitHub site and then again you can you can download the installer binary file that is SageMath 9.1 installer and hyphen version 0.6 0 executable.

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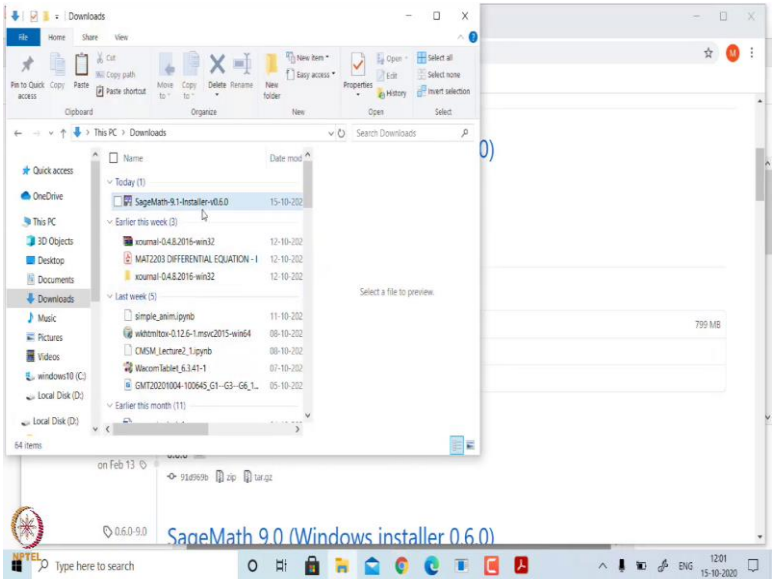

So, you can just click on this and download and since I have already downloaded let me go to that particular file. So, this is the file which I have downloaded. If I double click on this then it will open installer window.

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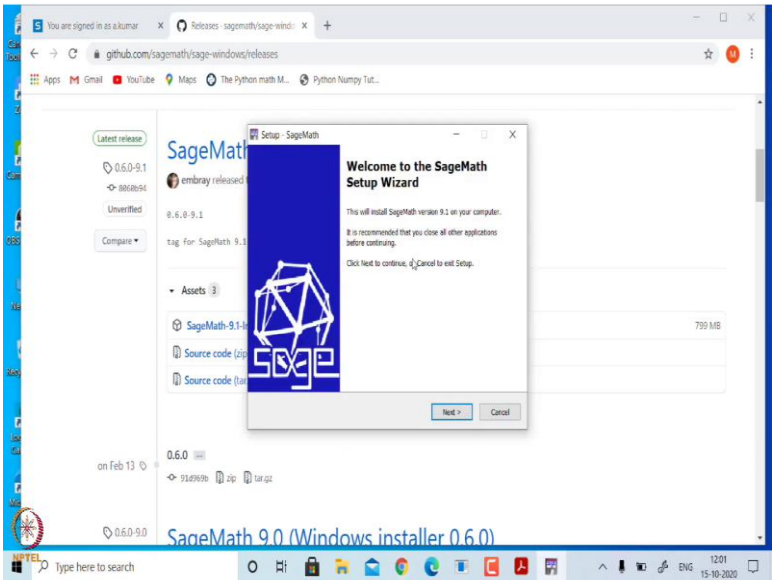

So, it takes little time let us see just one second, yeah. So, this is the installation window. So, it says Welcome to the SageMath Setup Wizard.

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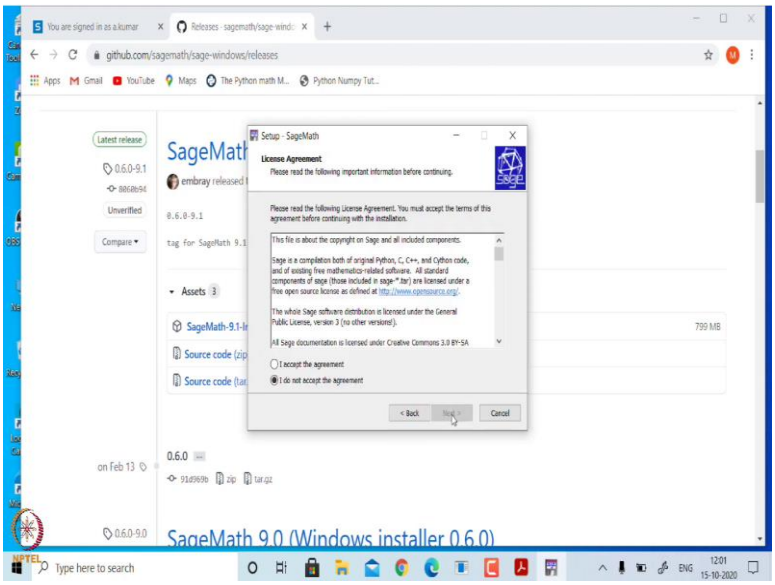

If you click just click on Next, then you may have to accept the agreement. It is also a good idea to go through this agreement.

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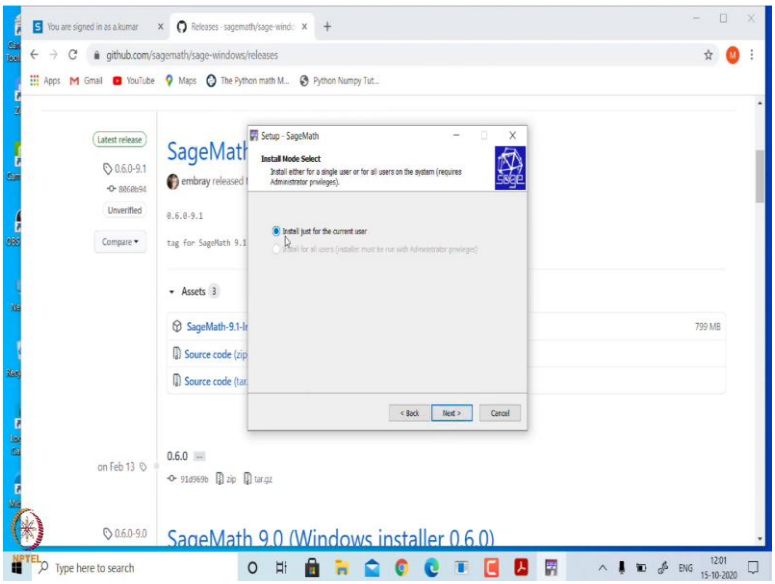

Then click on Next, it will ask you to install just for the current user you can also install for all the users from the administrator login then you click on Next.

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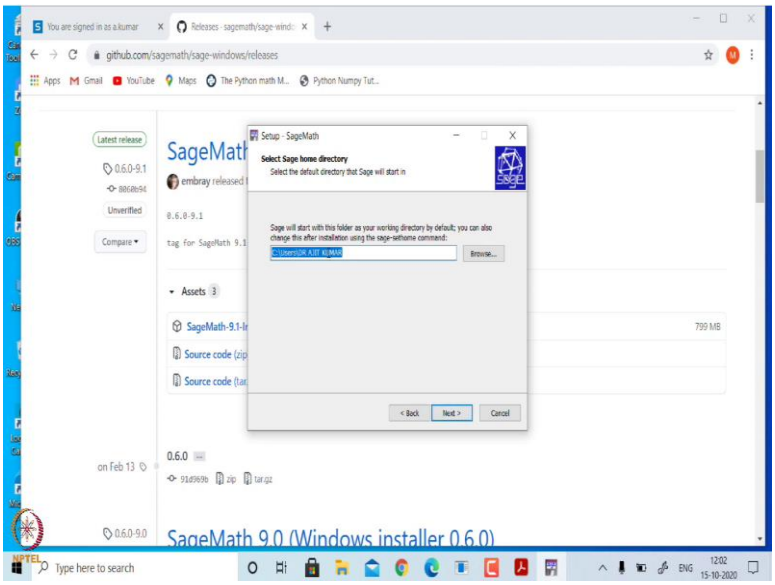

And, then it will choose some default directory, but you can choose different directory in which you want to install.

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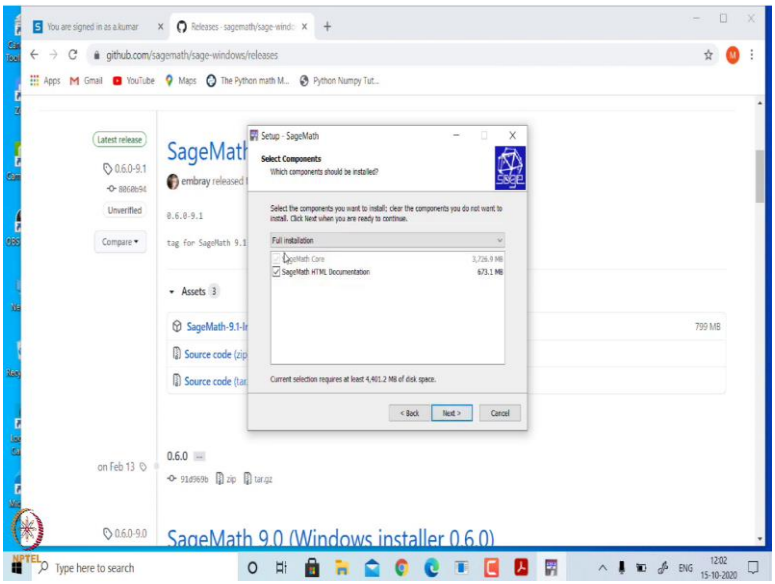

Let me go to Next then it is telling you that the components that you are going to install it is going to install SageMath Core and it also installs SageMath HTML documentation, but especially for the beginners it is good idea to install this documentation as well.

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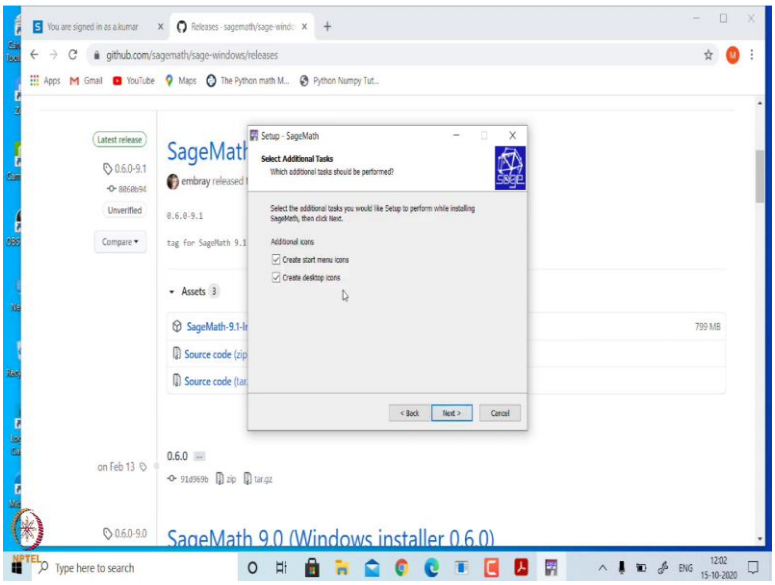

Then you click on Next – it is saying that it will create icons on your desktop.

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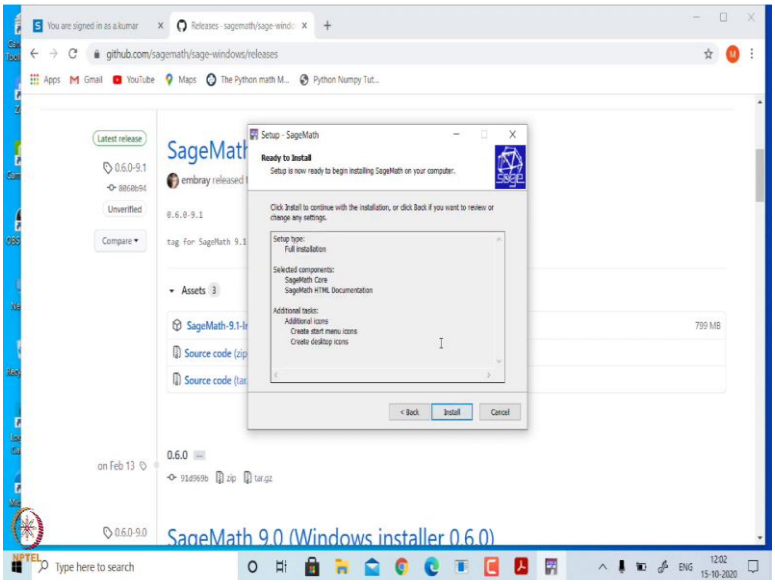

Then let go to Next and then it is asking you to click on Install and then it will install. So, since I have already installed it, I will not click on Install. When you install the when you click on Install it may take few minutes depending upon the RAM and the your the processor, it may take some time. For example, in on my computer which is though it is old, but it is I 7 it has taken about 12 minutes because SageMath is fairly big file.

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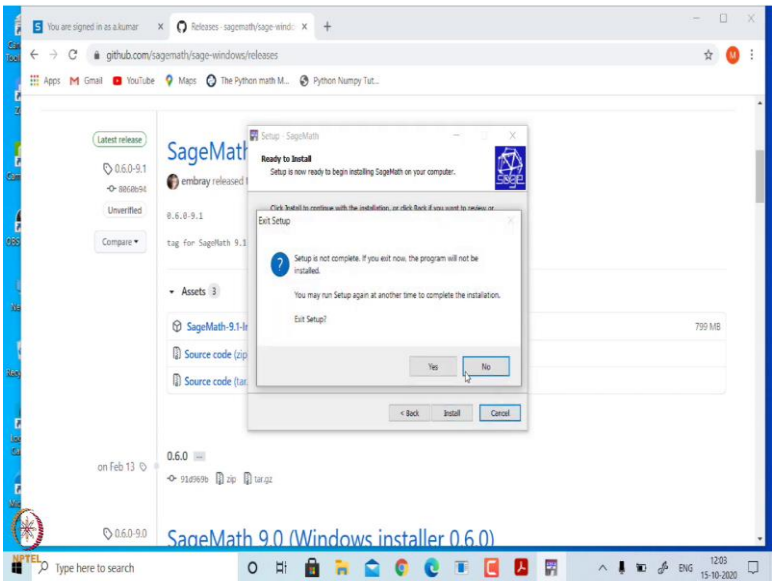

So, let me cancel this.

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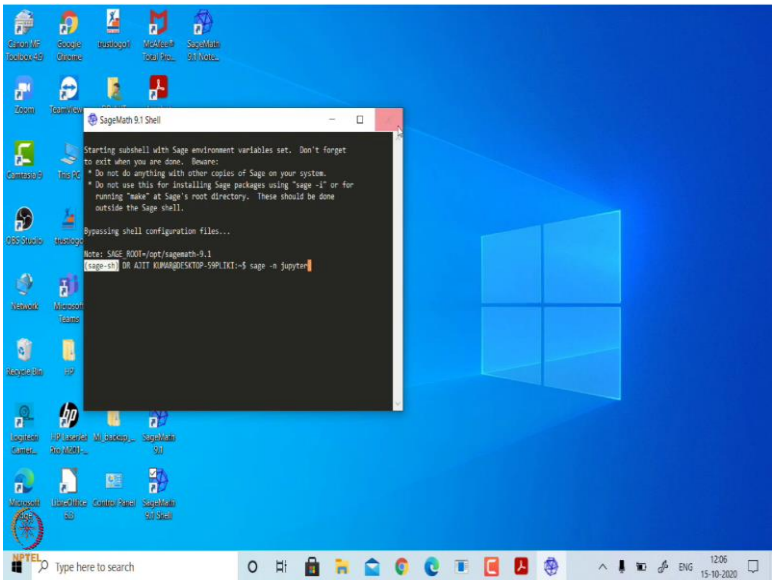

And, so, when you have installed this it will you will see three icons on your desktop one is SageMath 9.1, SageMath 9.1 Shell and then SageMath 9.1 Notebook.

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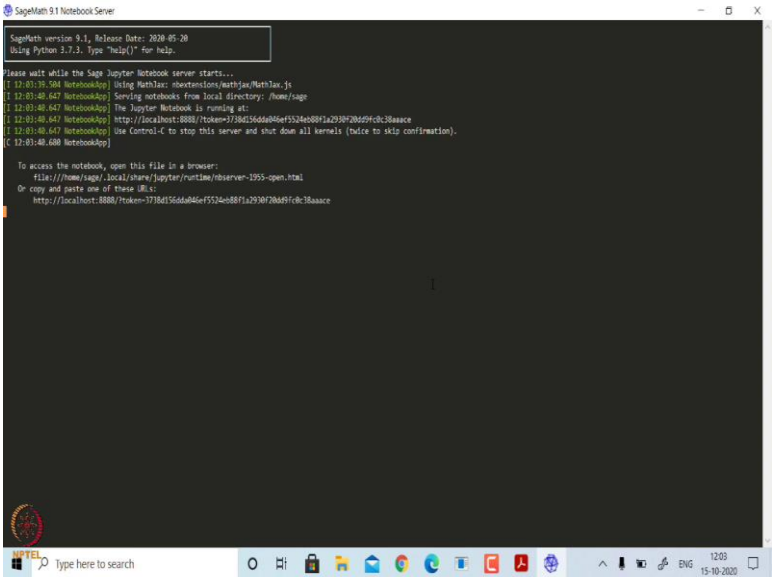

So, you can you can click on SageMath 9.1 Notebook. When you click on this, it will open SageMath from Jupyter Notebook.

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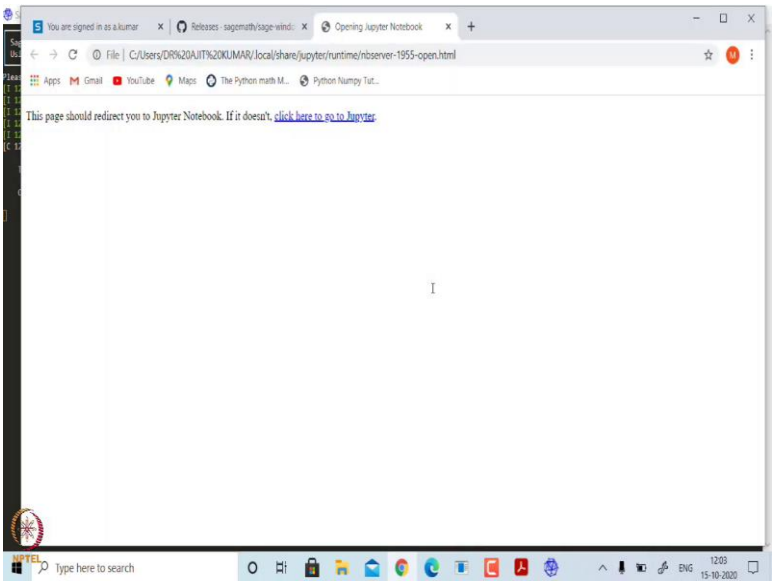

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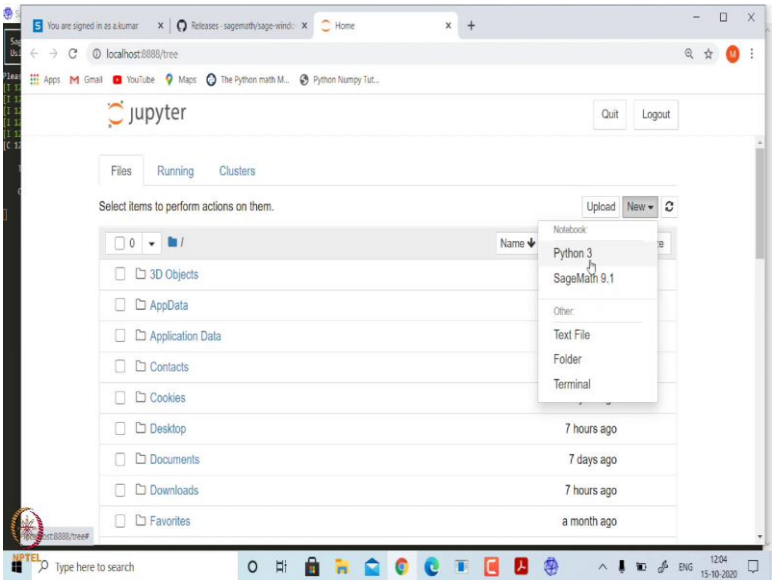

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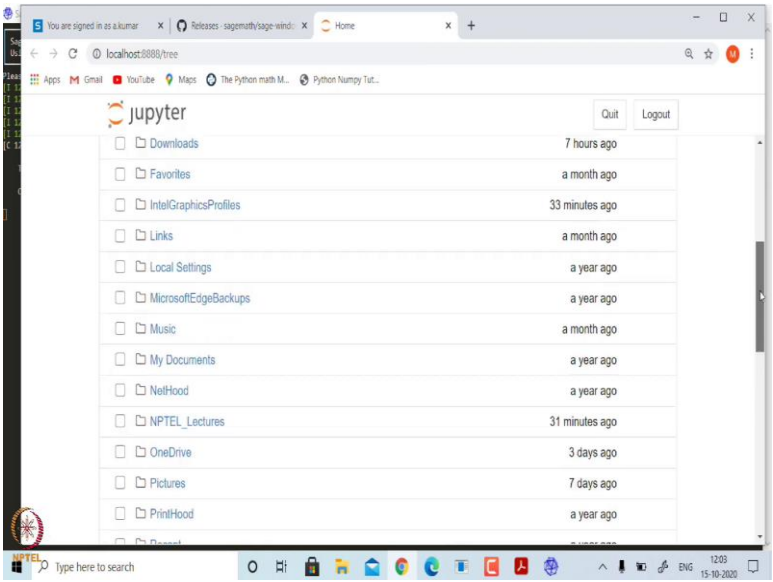

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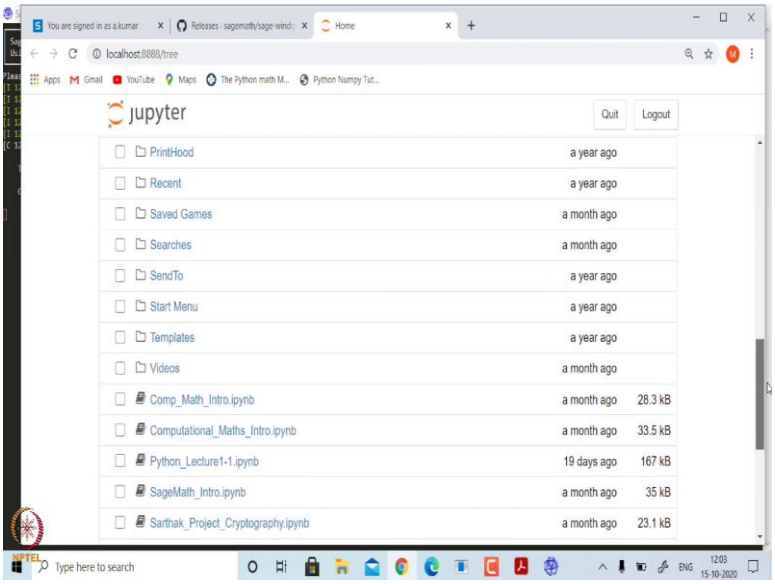

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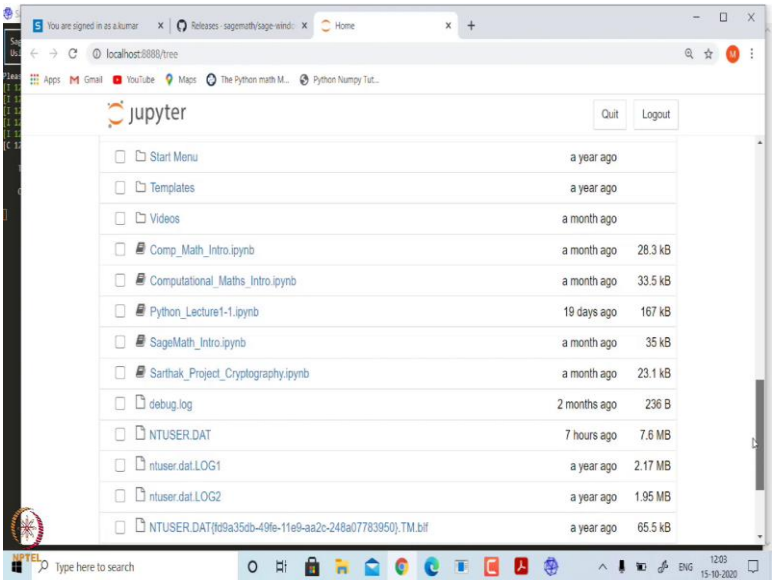

So, it is just starting the kernel and you can see here this is the Jupyter notebook home folder and this is exactly similar to what you saw when we were looking at Python from Jupyter notebook.

So, you can after this these are the your folders and files, you can go to new and then choose to choose Sage 9.1 or you can if you want to just run Python you can choose Python and if you have installed other softwares it will also give you option like R and Julia and things like that.

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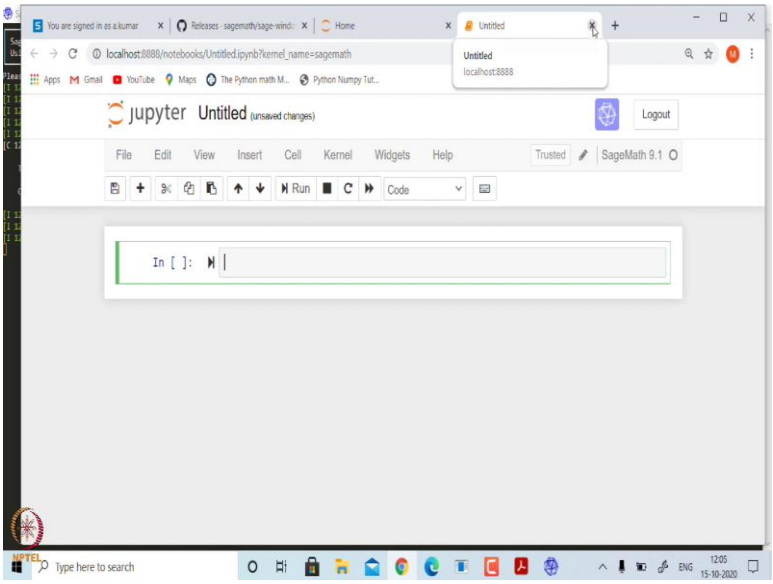

So, if I let me click here 9.1, then it will open a Sage notebook inside Jupyter notebook this is a cell in which you can you can. So, you can type any Sage syntax and execute exactly similar to how we did execution in case of Python programs.

So, if you want to rename this file you can just click on this and it will rename. So, anyway in a case, we will learn this from scratch from next class onwards, but this is how you get started when you have installed SageMath in Window operating system.

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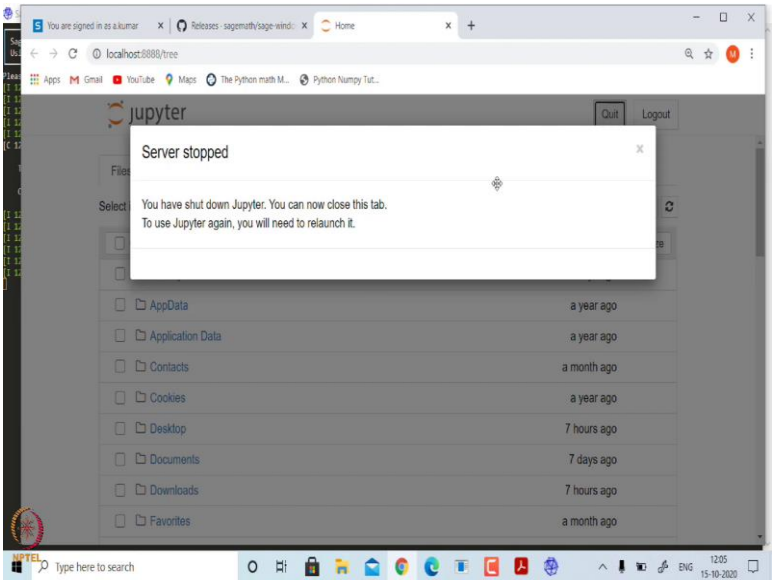

So, let me close this and we can even say Logout or Quit. So, if I say Quit, then you it says that you have shut down the Jupyter. You can now close this tab to use Jupyter again you will need to relaunch it. So, let me close it let me close this particular tab and that's it.

So, you are now let me again go to for example, desktop the other two icons we have SageMath 9.1 Shell. So, you can use SageMath from the terminal. So, you can after this you can start for example, I can say 'sage -n jupyter' it will start again SageMath notebook in Jupyter notebook.

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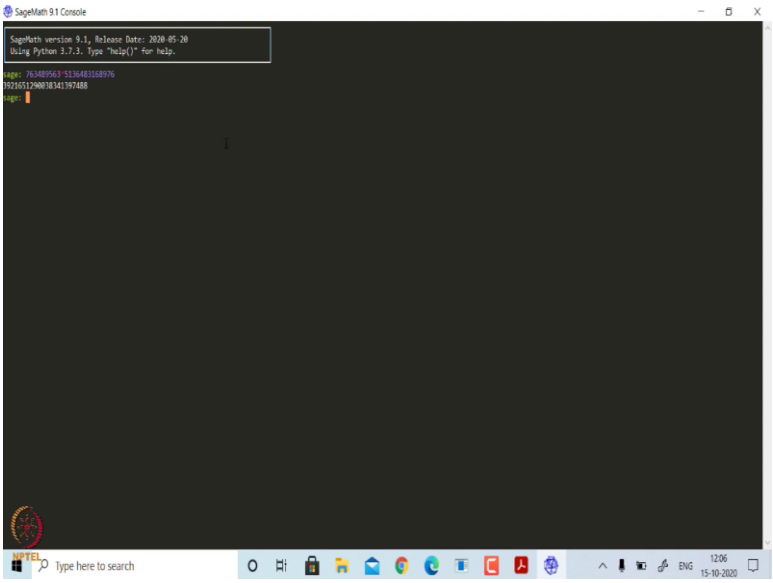

Or you can if you click on SageMath 9.1, then it will open SageMath in console and all the computations you can do from this console itself. Many people especially, those who prefer use to use Linux and UNIX, they prefer using SageMath from the terminal.

So, now, you can for example, if I take this number and star(*) another number. So, we are taking multiplication of these two numbers if I press enter it will give you the computation and in order to close this you can simply say Ctrl-D and that is it, you have exited.

So, that is the that is how you install SageMath in various operating systems including Linux, Mac and Windows system. So, if you want to know more about installing in

various other operating system you can open the installation Sage installation guide from it's website and then go through it ok.

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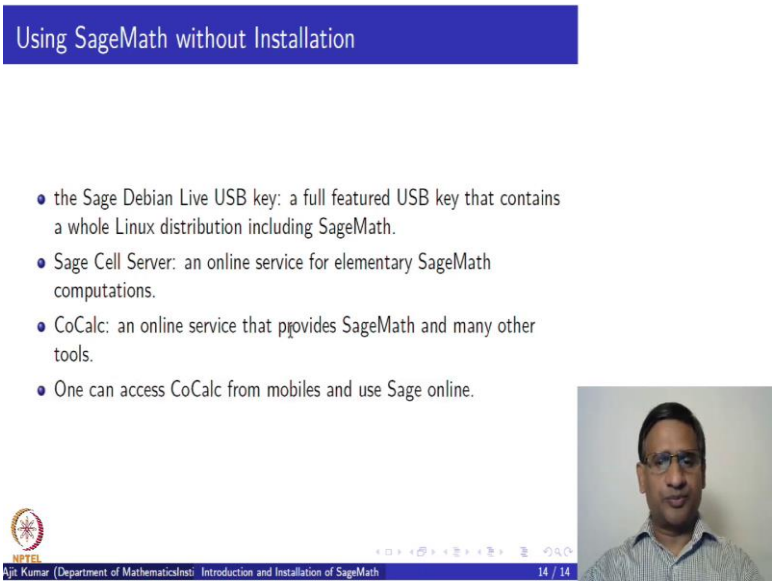

At the end let me also tell you how to use SageMath without installing in your system. In case you have some trouble installing in your system, one way to use SageMath is from it is website you can download what is called USB key that is through Debian.

So, Sage Debian Live USB key and you can burn this in on some USB key pendrive and then you can run SageMath, it will create what is called Debian system and there you can start using or you can even use online from it's website.

So, there are two ways in which one can do; one can use what it called Sage Cell Server and one can use CoCalc which is collaborative calculations and it provides SageMath it uses SageMath from the cloud.

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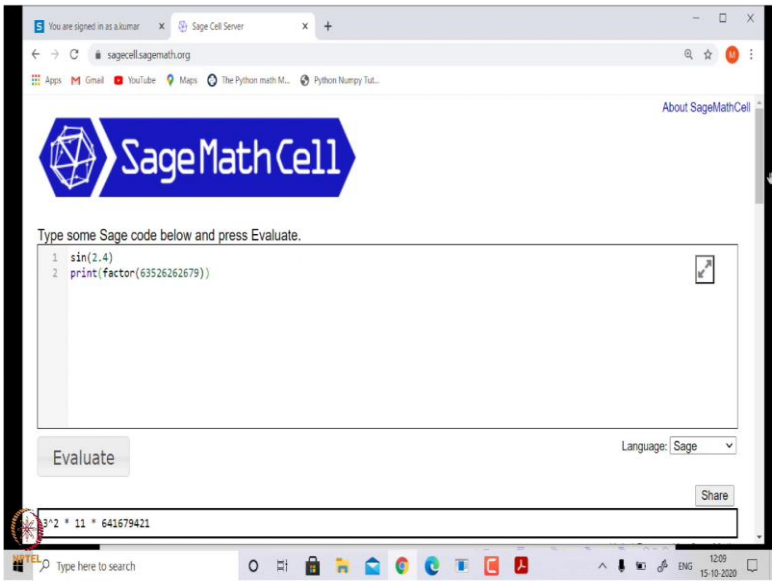

So, let me again go to this SageMath website. So, let us say sagemath.org and in order to use SageMath online as I said one option is to click on SageMath Cell and this is a cell in which you can type all the commands.

For example, I can just simply say tell me what is sin(2.4) and it will evaluate and it will give you output here. I can even say print me the value of let us say, tell me the factor of some number like this: 'print(factor(63526262679)' and it will give you output. So, these are the factors of this integer.

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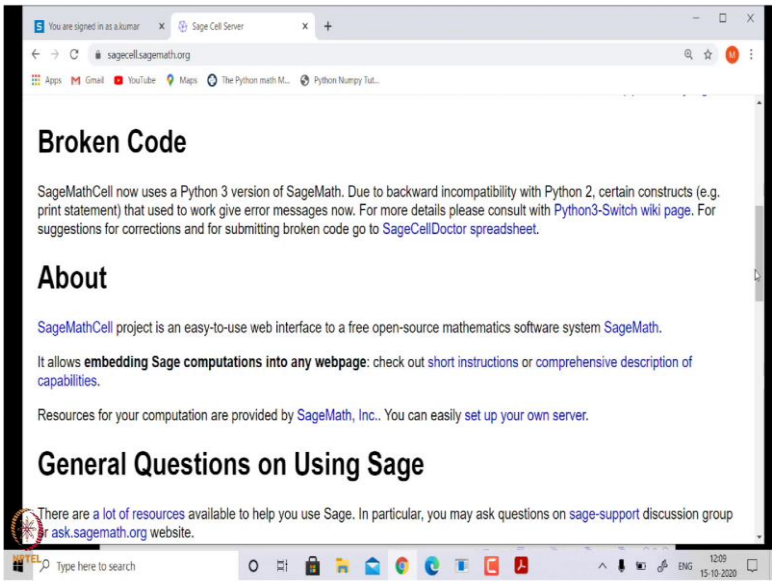

So, if you go down it tells you what is this SageMath One Cell it says that SageMath Cell of course, it uses now Python 3 version and actually what is it? It is a project and easy to use web interface to a free open source mathematical software SageMath and it allows you to actually embedding this SageMath Cell in any of your web page.

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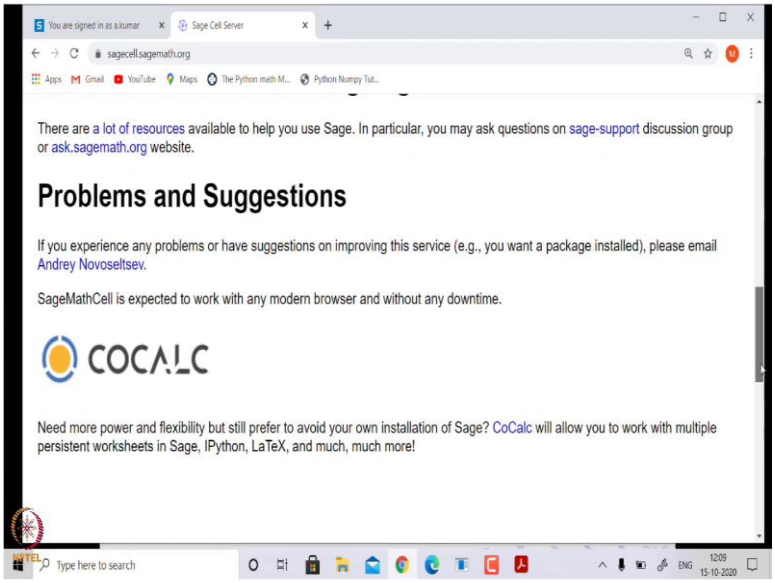

And, in this case the only drawback here is when you use these commands it may not be available next time. So, you can copy-paste these commands in some file, it could be a Word file, it could be Notepad file and some other or some other file. So, let me again go back to its website the other way of using SageMath is you can click on CoCalc SageMath cloud.

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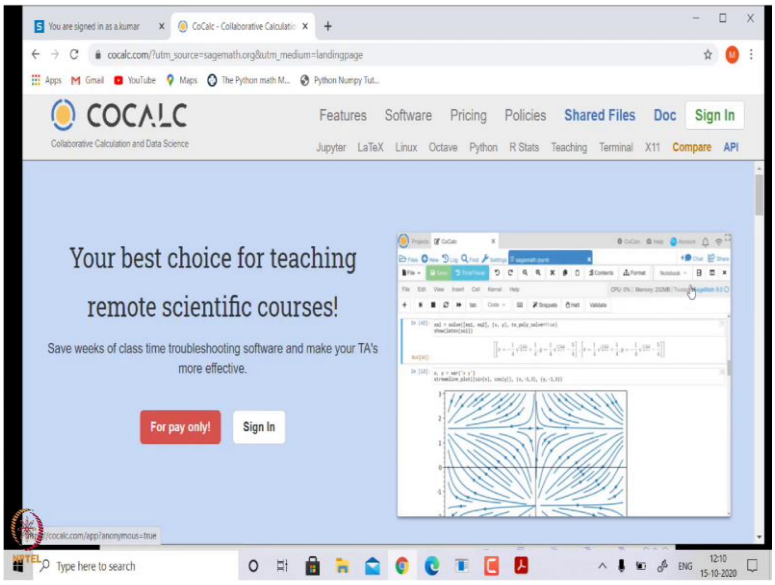

And, then it may ask you to create your login ID. Of course, this has somewhat limitations and in case you want more space more memory etc you may need to pay some money, but however, for using for personal use etc it is actually free. You can just create your own login ID and then you can start using.

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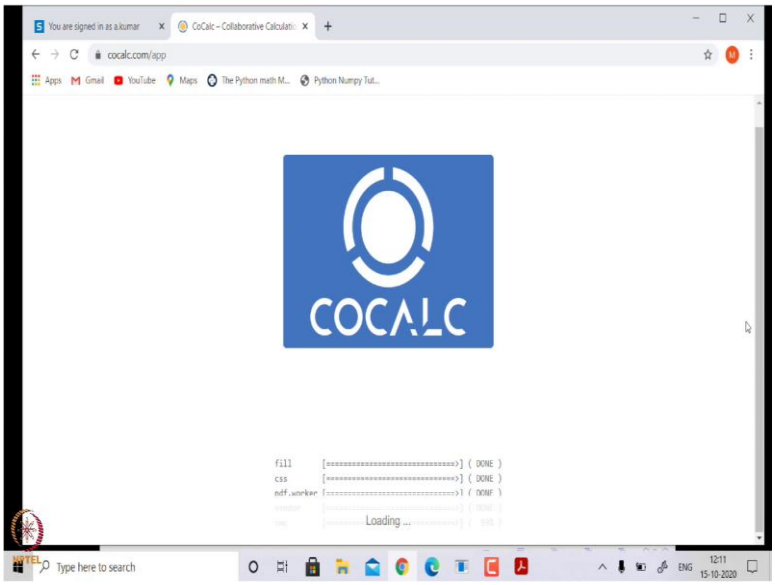

So, let me just click on Sign In and it may take little time.

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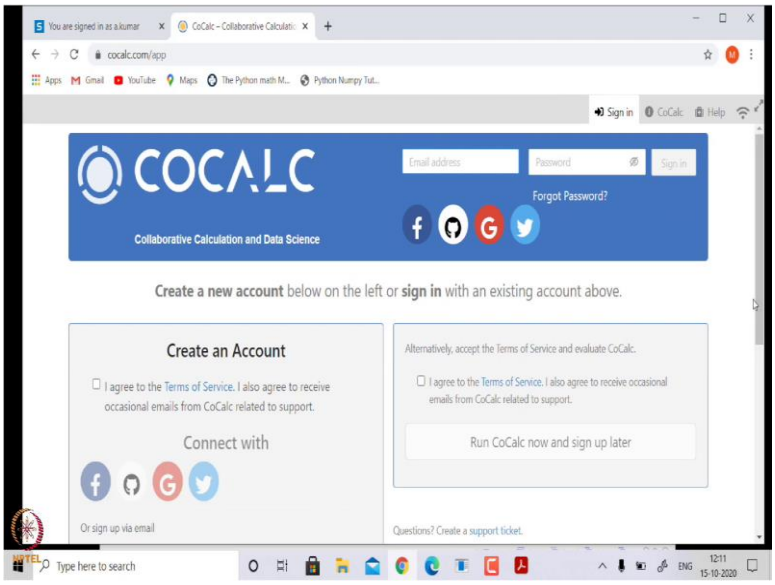

So, once you have clicked on sign in you can log in through your G-mail account or you can create your own account and then let me login through my account.

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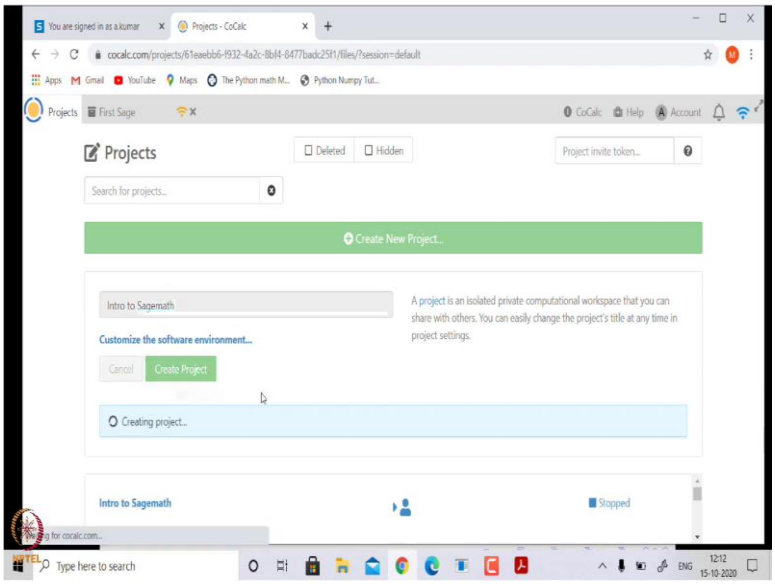

So, this is a this is an account which I have created. I can create a new project and give the name of this let us say Intro to Sagemath and then I can ask it to Create Project.

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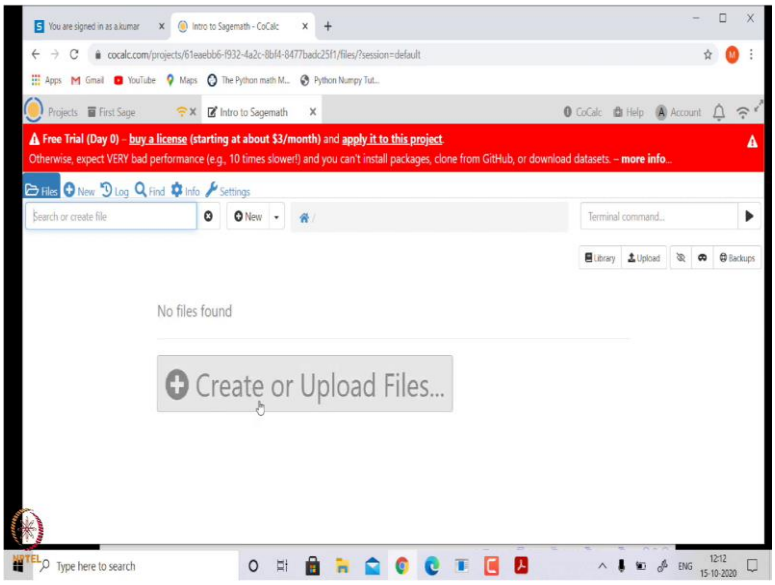

Once you have created this project it will open a worksheet. So, it may be little slow.

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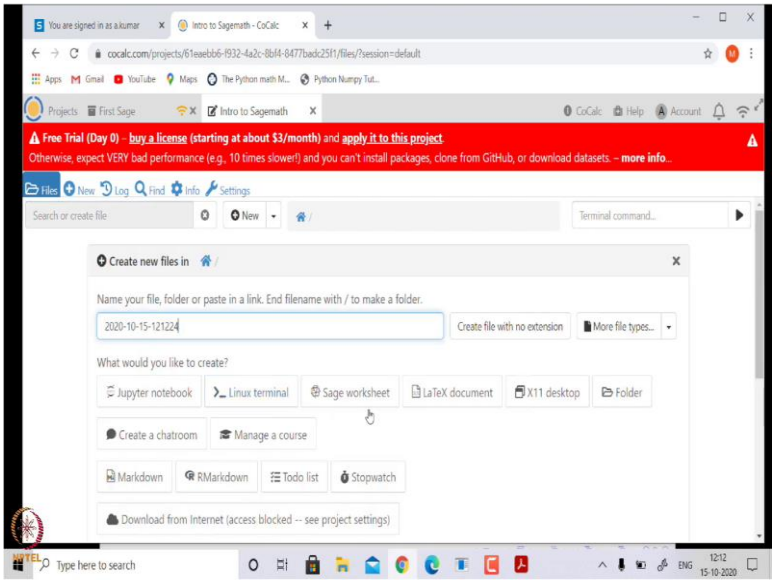

And, then after that you can create or upload a file. Since we are creating for the first time, I will just create on the click on this Create file.

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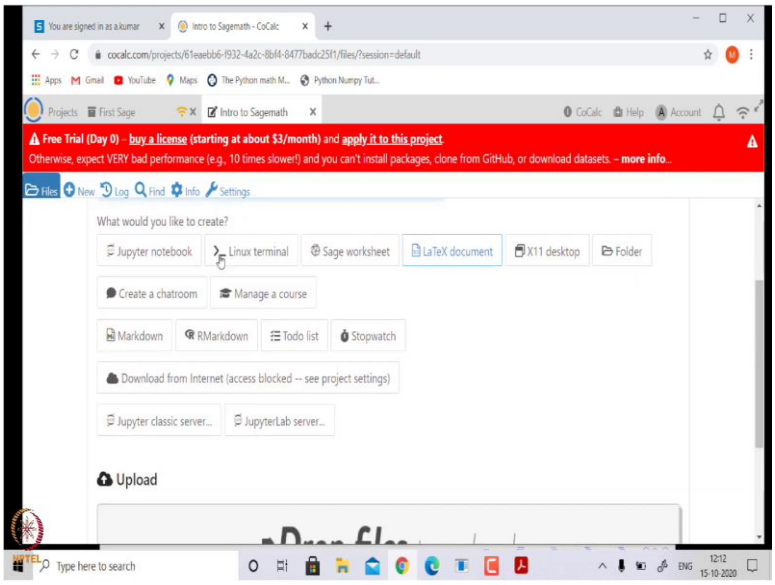

And, then it will ask you to choose the kernel. So, I can use Jupyter notebook kernel or Sage worksheet kernel or if you want to use other things etc you can click on Markdown, you can click on LaTeX document.

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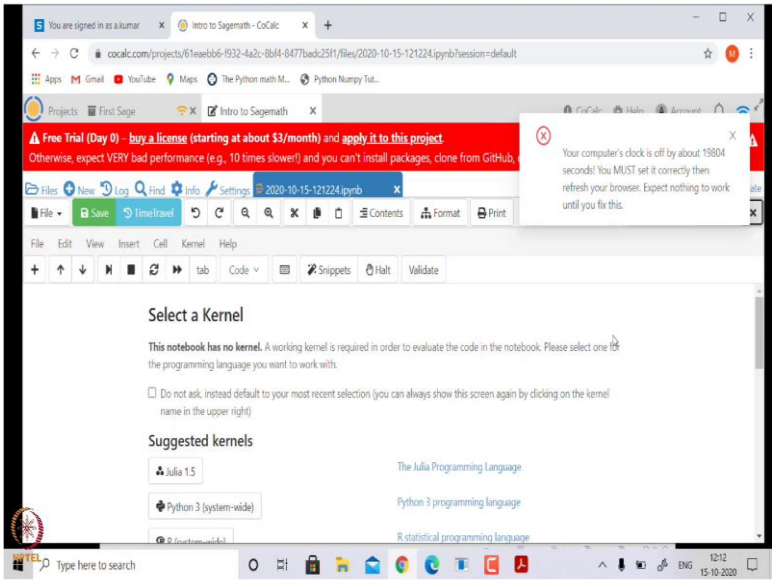

So, let me click on Jupyter notebook. So, once you click Jupyter notebook then you will see. Now, again it is asking me to choose which kernel do you want.

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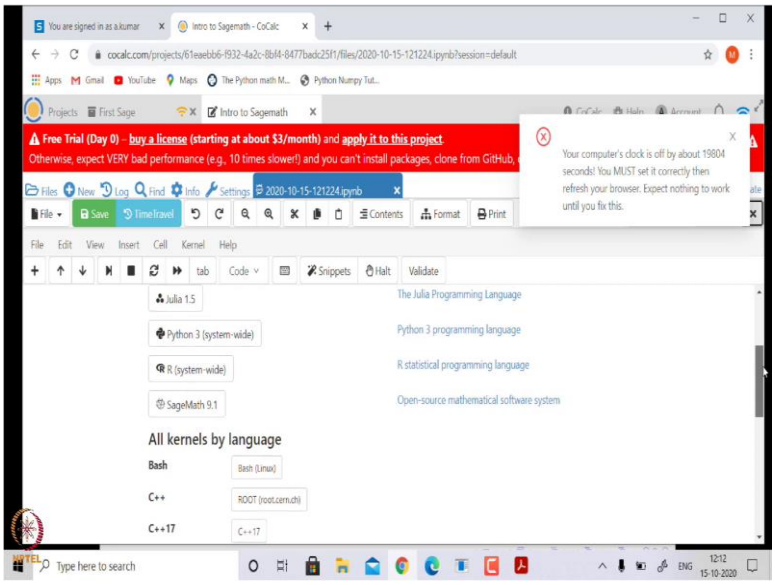

So, I will say SageMath 9.1 kernel and that is it.

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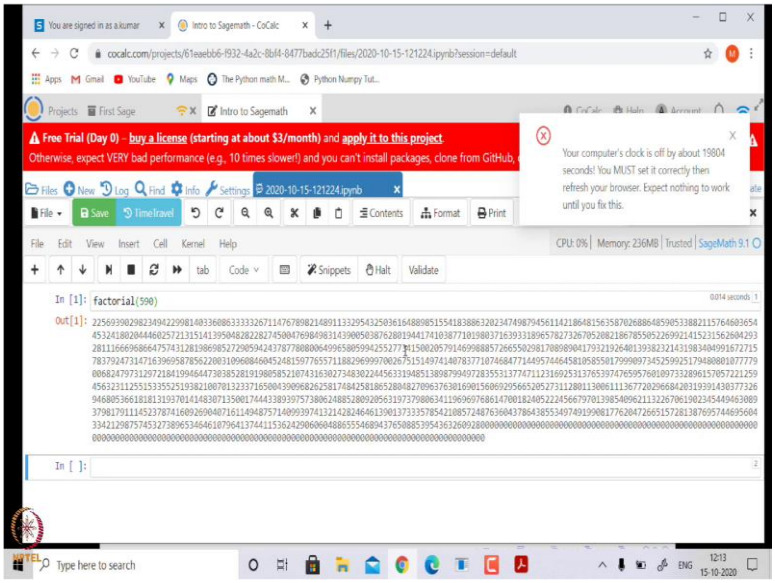

So, you are now ready to use SageMath online. I can let me type here say a factorial of some number let us say 590. So, it gives you this. And, the advantage of this using online all these codes which you are creating next time you can again see all these codes re-run and all these things you can save this including saving in various other format. So, this is the advantage.

So, in principle you do not need to install Sage in your system. However, it is good to install it will be faster to use, but in case for some reason you are unable to install you

can use it online. And, I mean and using online also it is not restricted it the full version is available online as well.

So, I hope by this introduction you should be able to install SageMath in your system. In the next class I will start using SageMath for exploring mathematics. So, I expect all of you to install in your system before we come to the next class.

Thank you very much.