Programming in Modern C++
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Lecture 42
Input-Output: Streams in C++

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Welcome to Programming in Modern C++, we are in week 9 and we are going to discuss module 42 - M42.

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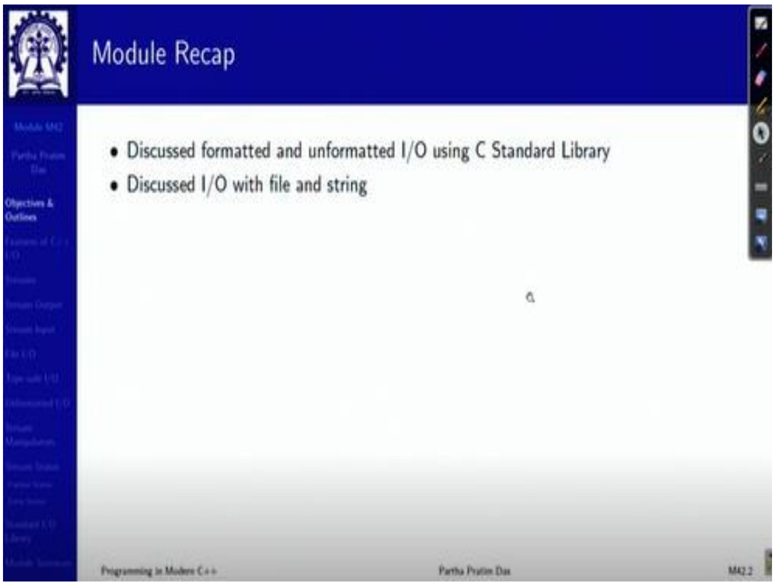

So, in the last module we have talked about doing formatted and unformatted I/O using C standard library, particularly the component stdio.h. We discussed I/O with file and string and specifically introduced the notion of files and streams and their association.

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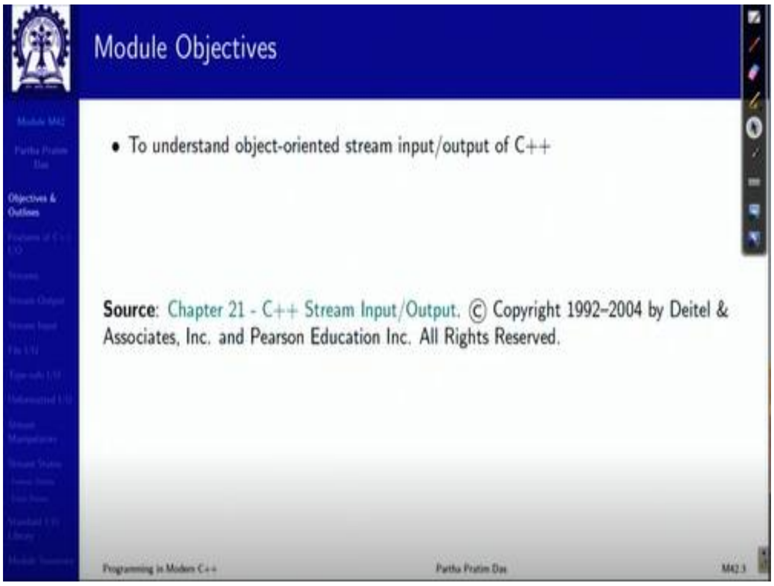

In this module, we are going to discuss about the object-oriented stream input-output of C++. How does C++ do it? Obviously, stdio.h is also available in C++ as you know as cstdio in the std namespace. You can use all those functions, but certainly you can do things in a lot better way in terms of using the object-oriented stream operations in C++.

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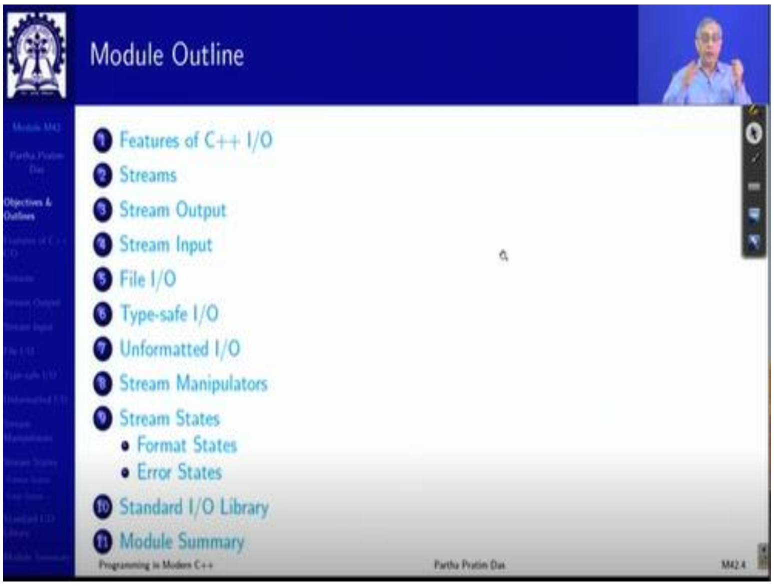

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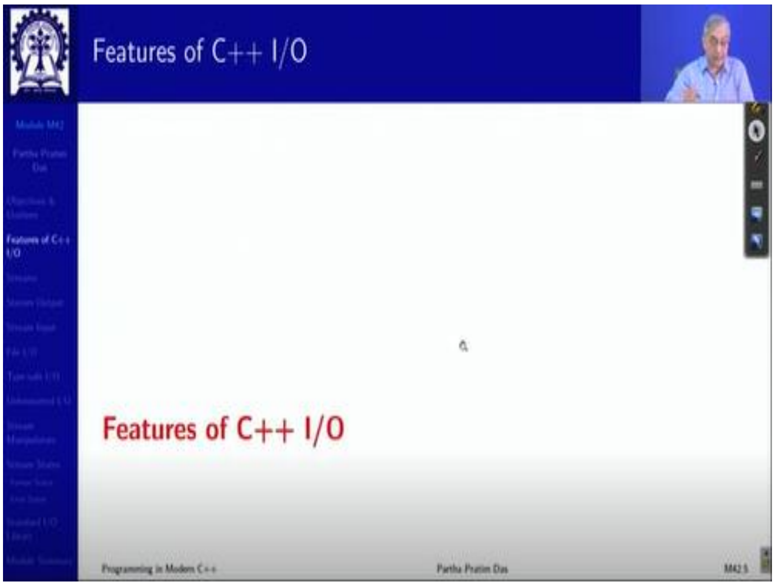

So, let us identify what are the key features of C++ I/O.

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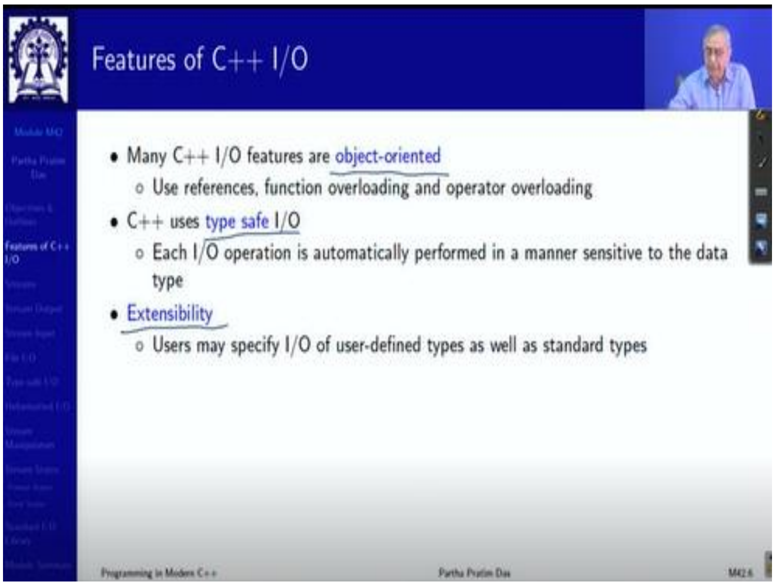

There are three key features: one is most of the C++ I/O features are object-oriented, like in the C stdio.h, you had everything as a collection of functions, procedural. Here, you will have most of the things as classes and objects instantiated for those classes, and you will deal with the member functions of those classes. So, that is, that is what makes it really-really flexible and you know, gives you all the advantages.

The second is, C++ uses type safe I/O that is in C when you are trying to say write a value say you are doing trying to write an integer value (int type of value) you will have to rightly specify the format in the corresponding position. If you write %d it is good, but if you write %s and try to write an integer value, you will have unpredicted results.

And this correspondence of the type of the value you are writing and the format specification that you have given is to be managed by the programmer, which is a big overhead and in the source of huge number of errors that have happened over time and keeps happening. But in C++ it is type safe, you do not have to specify the format to write as you have seen. The format is picked up based on the type of the data you are going to stream we are going to write. You can just really say that I want to write this I want to read this, compiler knows the type of the variable and accordingly chooses the right format.

And if you want to change that default choice, there are also additional features given to you So, type safety is a big feature. The third that you have is extensibility that is in C. If you have to write or read a particular structure that you have defined, user-defined data type So, to say like complex, you know, you cannot have any specific function specific format string for doing that, because the format strings were created before your particular your program is done. So, you have to take it component by component always break it down to the lowest level of built in types and do the read write this is extremely inconvenient.

Whereas in terms of C++, you can actually use the function overloading we have discussed enough of that already. Particularly the operator overloading in terms of the streaming operators and define your own input and output operators for your own type. And then just keep using it. And it will have all the behaviors of object orientation and type safety as we have for the building types. So, these are the three major features of C++ type of I/O and that makes it really powerful.

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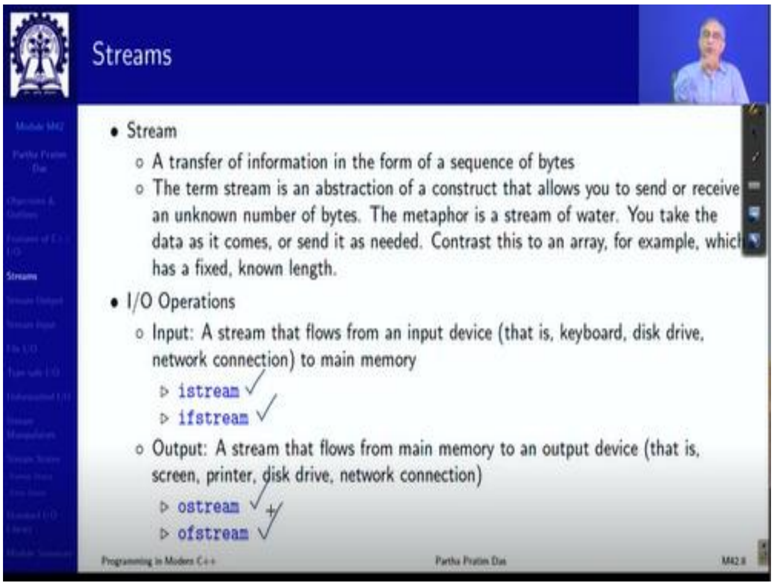

We have already talked about streams So, just a quick reminder that it is a transfer of information in the form of a sequence of bytes. The term stream I said it comes from the natural you know, what a stream and for doing I/O operations here what you have is you have certain stream classes defined. So, if it is an input device then it was represented by istream, if it is I mean typically stdin or you can have a file defined or associated as an ifstream object. You can understand that i stands for input f stands for file.

Similarly, for output you have ostream and ofstream. So, these are the classes given in the library, so that you have all that you need to do is to just specify the physical file object or the physical device with the corresponding stream type and everything else will then come from that stream type class. So, you have already seen this but not very consciously though.

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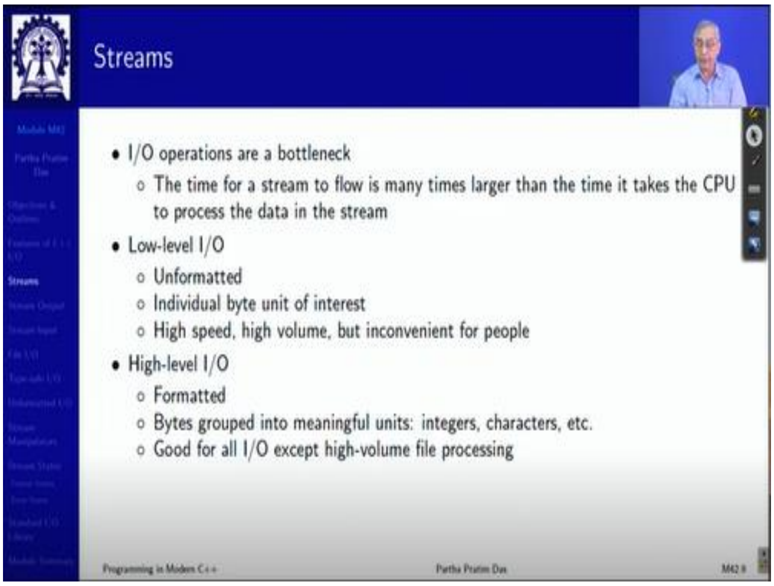

Now, again a reminder is I/O operation is a bottleneck because I/O with the disk is very-very slow. So, you can work around this if you have a low level you that is what you do you for individual bytes of interest, you can just put them in the buffer and flush them out high speed high volume can do. But high level I/O which is typically formatted needs to be grouped in terms of the typical data types and they are good for all kinds of meaningful use, because you cannot go down to low level and do things all the time.

So, the streams give you a mechanism by which you can do a high level I/O with its advantages, but underlying it uses the buffers and all the padding and all those to make sure that you get the efficiency of the low level I/O that is a basic process of the stream.

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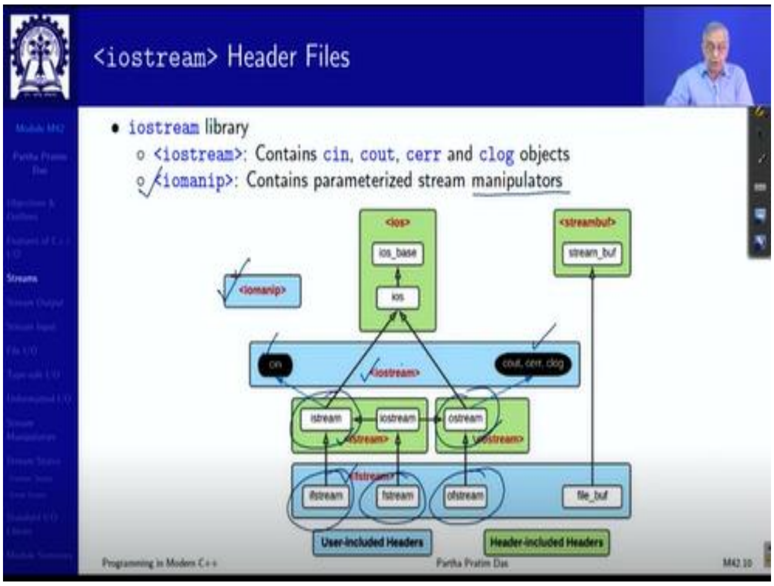

So, to start with, let me introduce the stream libraries that we have. You are already familiar with I/O stream which is this library. You can see here in this diagram. I am trying to show the where basically there ISA hierarchy of the major classes that are involved. So, you can see that you have your I/O stream is one com. So, let me explain the notation. So, whatever you see in white, these are your classes. So, you have a hierarchy diagram amongst them. What you see in terms of boxed and red names are the standard library components.

So, these are the headers that include the definitions of these corresponding classes. Whatever is in blue is what we will typically include in a user program. Whatever is green is included from these files, but we do not need to directly include them.

So, if we if you recall into this, you will know that we have always started by including iostream, So, what do you get? If you include iostream then you actually get four streams, which we have always used the cin for input, cout for output, and there are two more cerr for error reporting and clog for log reporting.

Since we have not worked with the files, we have not included this. But this will be required to be included if I want to work with files, input and output both. So, it has fstream, it has ifstream which is input file stream, it is output file stream and iostream. When you include iostream it actually in turn includes these two headers which we do not have to specify which has the istream and the iostream for input as well as output.

Now I have mentioned here another which is iomanip. It is a little unnatural name what it means input-output manipulation (manip comes from manipulator). So, if you include iostream we for every data type you get a default formatting information in terms of what is the size, what is the weight, written alignment, and so on so forth.

But if you want to change that, you want to specifically widen the size shorten the size, you want a left justification, you want a right justification all of this, then you need to do this stream manipulation through this iomanip since we have not done this before, we did not require this earlier. So, as you can see, to summarize that, you will all that you will need to remember is including iostream for standard input-output, including fstream if you are doing file input-output and including iomanip if you want to manipulate the formatting for finer details.

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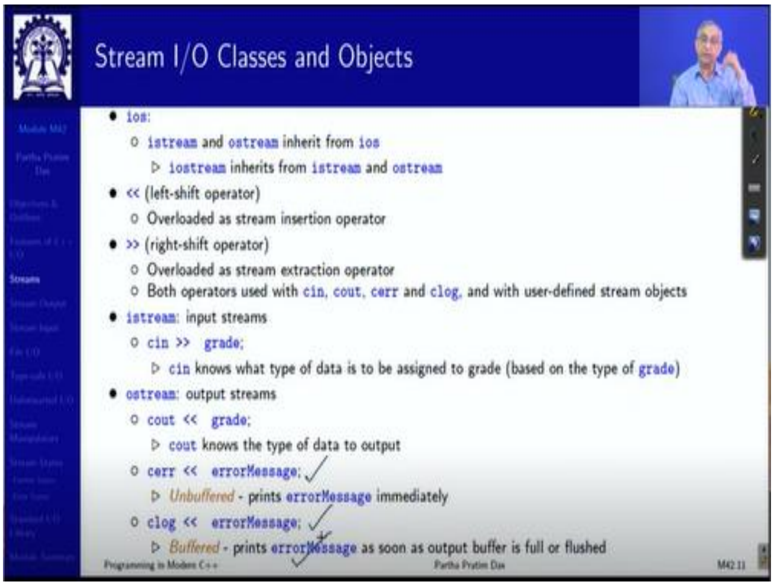

So, with that, let us take a quick look into the stream classes and objects. So, at the top you have ios which is the basic istream and ostream come from there you have, in that you have for the two operators which look like left shift operator for output streaming right shift operator for the input streaming. Then you have istream, which has cin. Then you have with that you have ostream with which you can do up to cout you have seen this several times.

You can at the same time do cerr for printing unbuffered messages immediately, like cout, as I said is buffered. So, you may write quite a few things, but it comes from the console, maybe at a later point of time. But cerr it will come immediately because error is very important to report. Whereas there is a logging clog where you can just log the things that are happening, so, it is not unbuffered it is buffered because you do not need to look at the log at every point, whenever the buffer is full, like the cout when the buffer is full or when needs to be flushed, it is put together.

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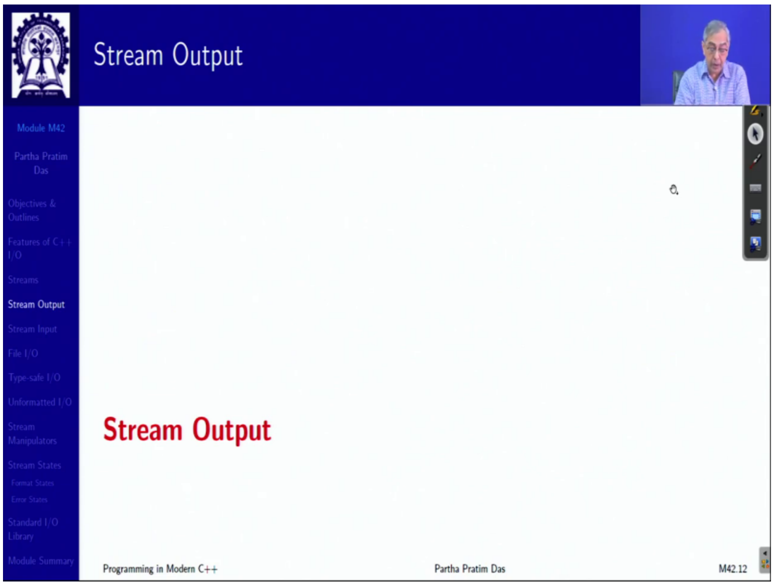

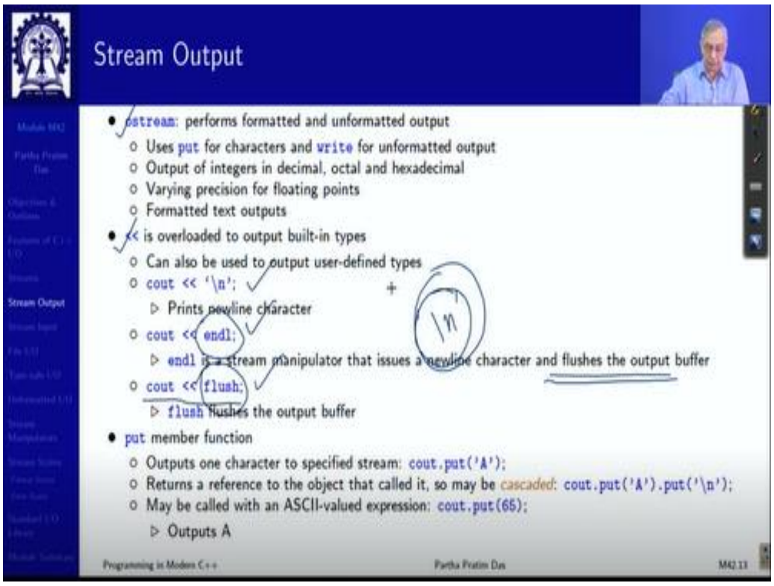

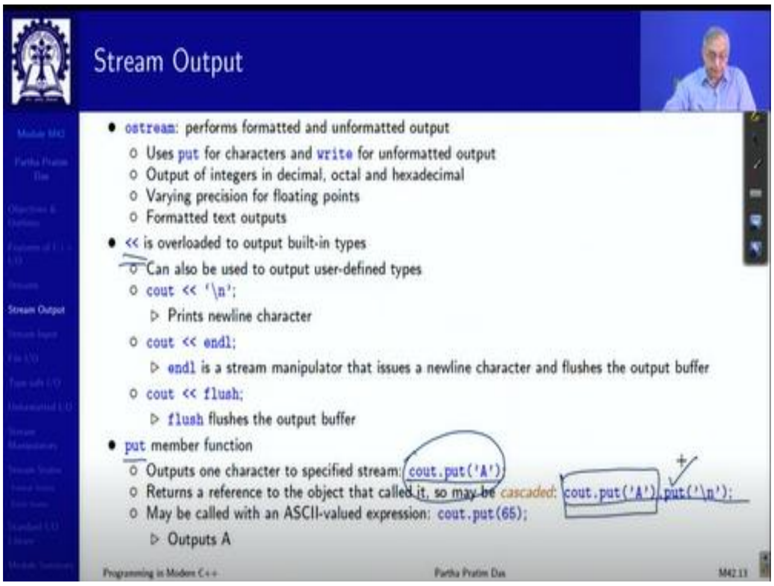

So, coming to stream output, there is not much to add. It is on ostream this operator. These are the typical ways to write just I would like to mention that flush. Suppose, if you do if you are writing, then it is being written on the buffer. And you are not being able to see it on the console, because it is just being written on the buffer. So, if you want to make sure that whatever you have written is shown on the console, then you can do it flush and the way to do this is to just output flush like here you do a flush along with a newline.

So, endl is just not a newline, endl is not equivalent to this. endl or end line is actually a manipulator which puts a newline, but after that it flushes the output buffer. If you just use new line then it you may find that actually the newline has been put to the cout, but you are not seeing it on the console.

Similarly, for you know kind of unformatted or character I/O you have put function member function which you can call on the cout. As you can cascade your formatted I/O your object I/O you can also cascade the character I/O like this cout.put. So, basically you can make out that the result this will put A on to the console and it will return cout again. So, this again becomes cout. Exactly the same behavior, which we see in terms of this operator you have seen we have written that we have seen that. So, you can again do a putc and keep on doing this.

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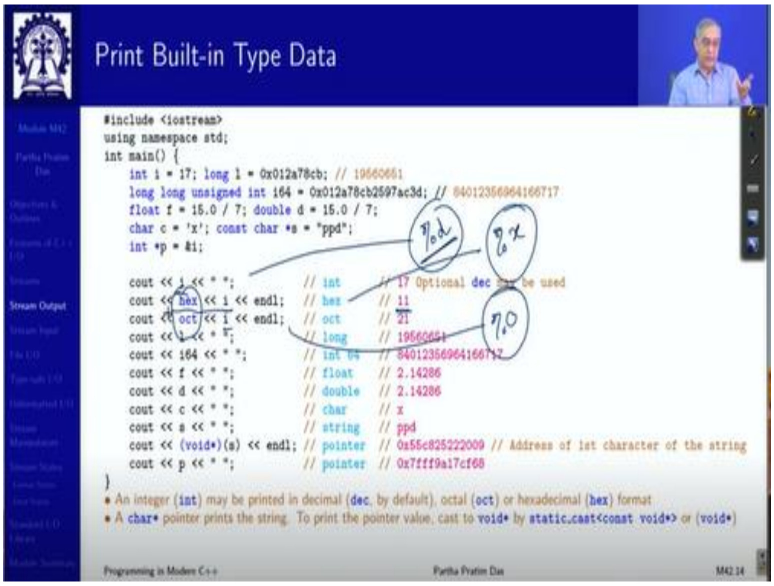

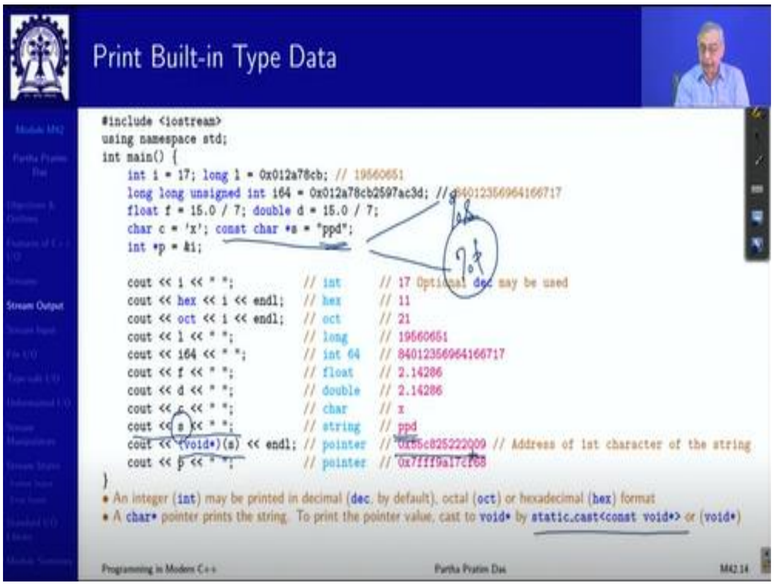

So, this is the basic streaming output. The earlier example I showed in the module 41 regarding using the printf the same example I have now written in terms of cout and you can see what all are getting printed. The only two points to note here like this you will get with %d in printf, and this you will get with %x, this will get with %o. You do not have these in C++ because it is being derived from that type.

So, if I write i then the default format is %d. And whatever %d will do write it in decimal. So, if I want to write it as hex what do I do? I just do this very nicely just yes cout hex than this. So, what it does is? It streams hex first onto the cout, sets it in the hexadecimal mode and then when i comes then i will be printed in the hexadecimal mode. So, you will get the printout, print as 11, rather not 11, one one because it is a, it is a hexadecimal value.

So, these are again the stream manipulators. So, you can very simply like we have seen endl, we have seen flush, hex, oct or other manipulators that you can very frequently use when you have the same type of data to be printed in different other forms that you want.

Here, if you have this character pointer, you can print it as a string by using %s. But if you want that pointer value, you can print this that by %p. But here, when you do it with cout in C++, when you do it ostream the type it knows for s is char* and char* is a string C style string understanding for here. So, if you output s, then it will be output as a string, you will get this string. So, how do you get the value of s value of this pointer which you could get as %p. You cannot get that directly, so all that you need to do is to erase the type information from this pointer.

So, you can use a C style casting to void* which again you should not do, you should do a C++ style casting cast the constant char* to const void* and then use it and in that case it will not know what type of value it is pointing to. So, it will not try to interpret that it will simply print that value and you will get the pointer that is address of the first character. So, these are the two basic differences from whatever we know in C.

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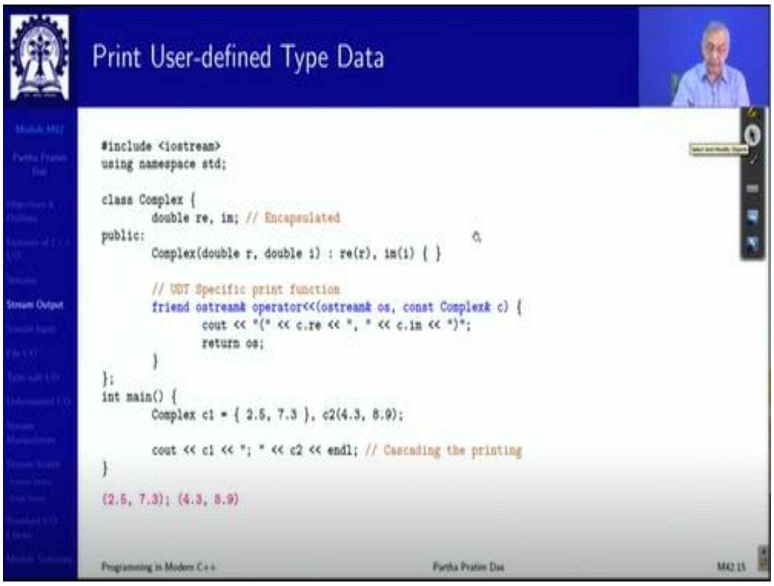

In terms of user-defined type, obviously, you have a big advantage because now you can define overload your output streaming operator and put it as a friend function in the class and cascade and write the user-defined objects exactly as the built in objects are written. I will not I am not going through these details, because you have already we have already discussed this at length earlier.

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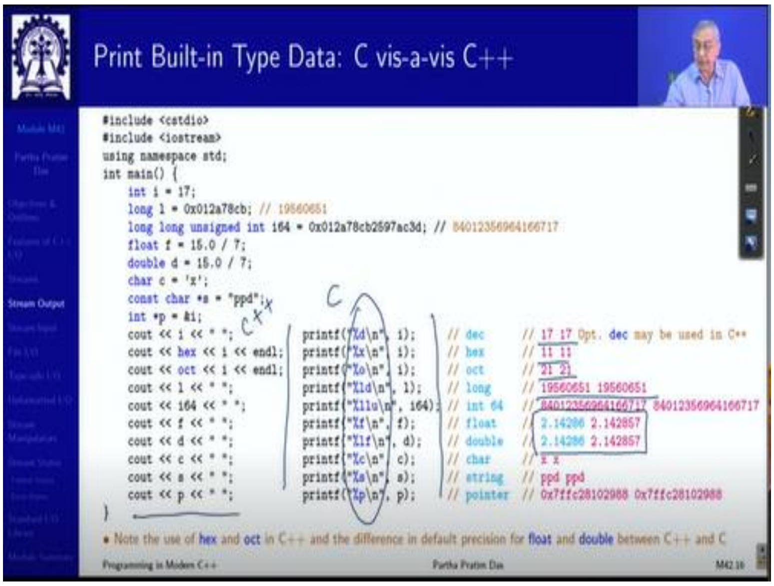

This is just a comparison of how it writes between C++ and C. If you write the same similar things in both, you will find that, these all actually write identically. Though there are some differences in cases. Here when you are writing float or double the default precision of %f for %lf is different from the default precision being taken.

Of course, you can change that by streaming an appropriate manipulator of precision or set precision. There is a set precision manipulated by setting that you can change this precision and make them identical otherwise, all of this will look very similar and you can you can very easily when you write it side by side, you can very easily see that all these information which you will have to have in your mind or to go back to module 41 slides and check the tables that have given and carefully construct you do not need to have any one of those. Here are very simple you just say these are value I want to output that is it. So, that gives you a big-big advantage.

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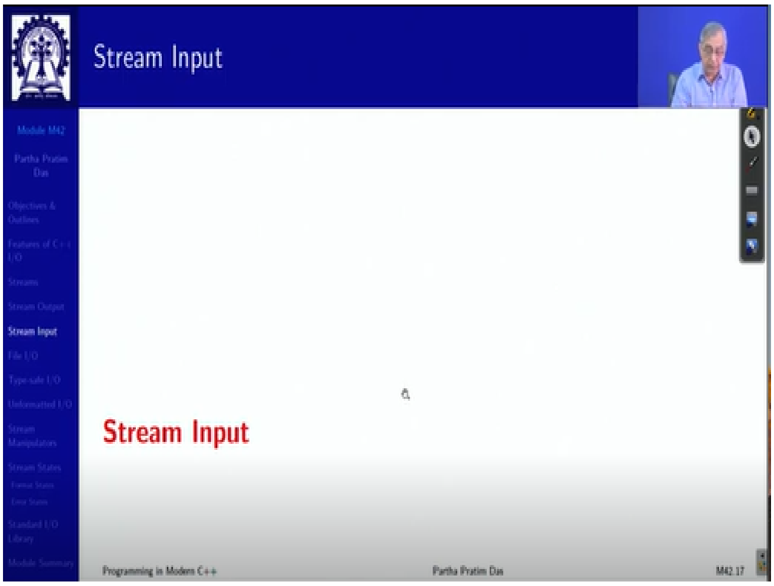

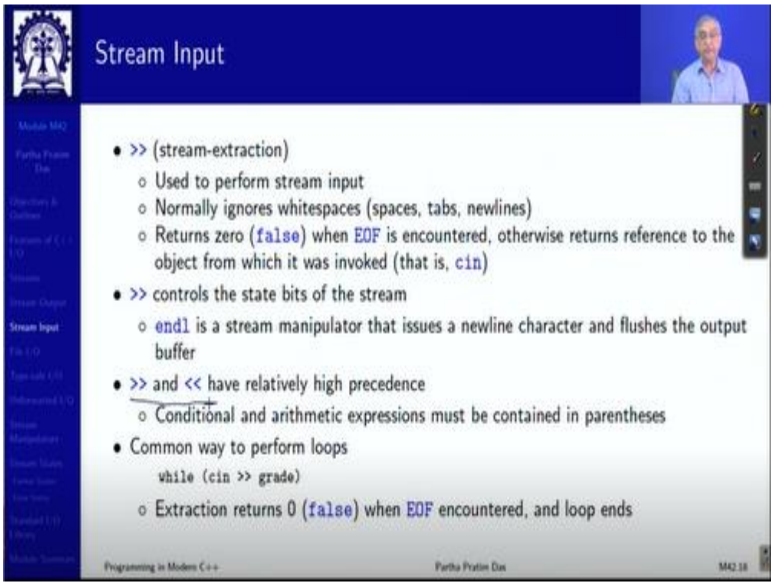

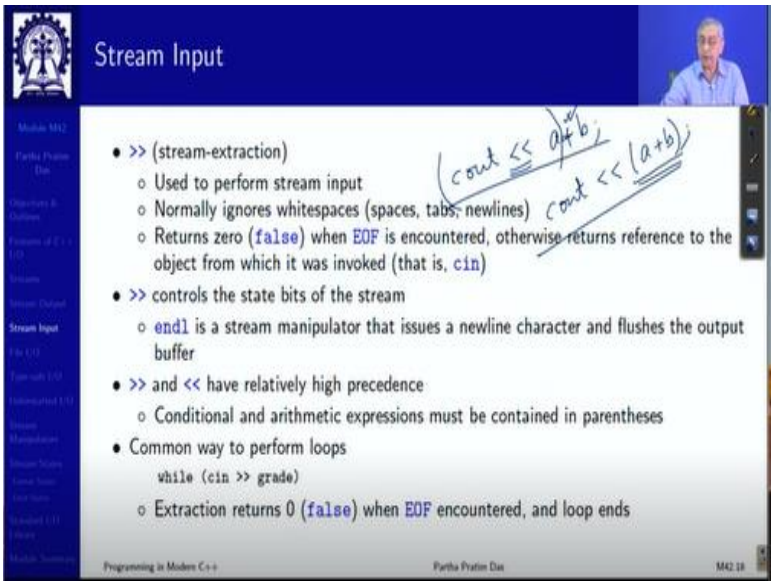

Anyway, if it comes to input, it is obviously very similar. It is a stream extraction, as long as you do not get to the end of the stream or end of file, the extraction will happen successfully and the input streaming operator can be can control the state of the bits that are coming in. And obviously at this point, it will be good to note that both of these operators have pretty high precedence. So, if you have some conditional or some, you know expressions arithmetic expression.

For example, if you want to suppose I want to write cout << a + b. If I write this it will be interpreted as because this streaming operator has higher precedence than plus. So, this obviously is not what I am meaning. So, it is always good that when you write expressions in your input or output streaming, always put them in parenthesis to make it safe. So, now this will happen and only that result will be output to the stream. Similar thing will happen for input as well.

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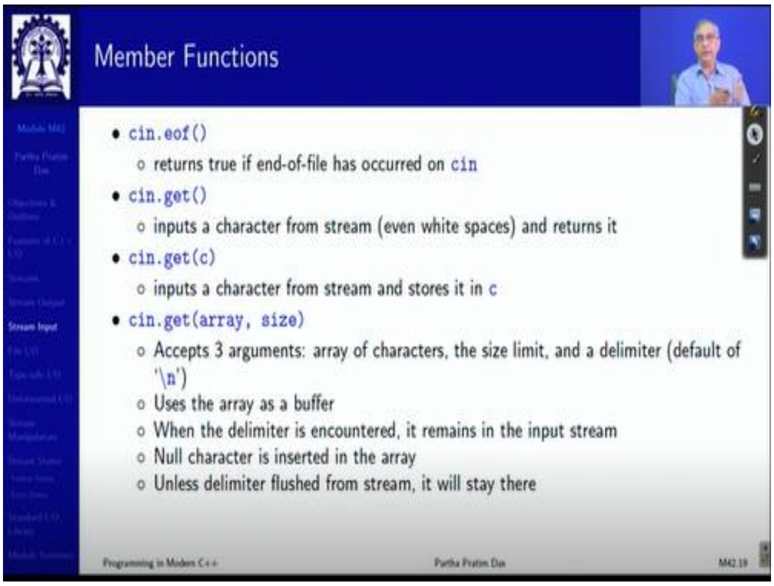

There are a number of member functions for cin as well, which, like eof tells you, if you are at the end of the file, which you need to know, you can have character I/O using get or getc, get array. So, these are the different ways to do the corresponding operations in the istream domain.

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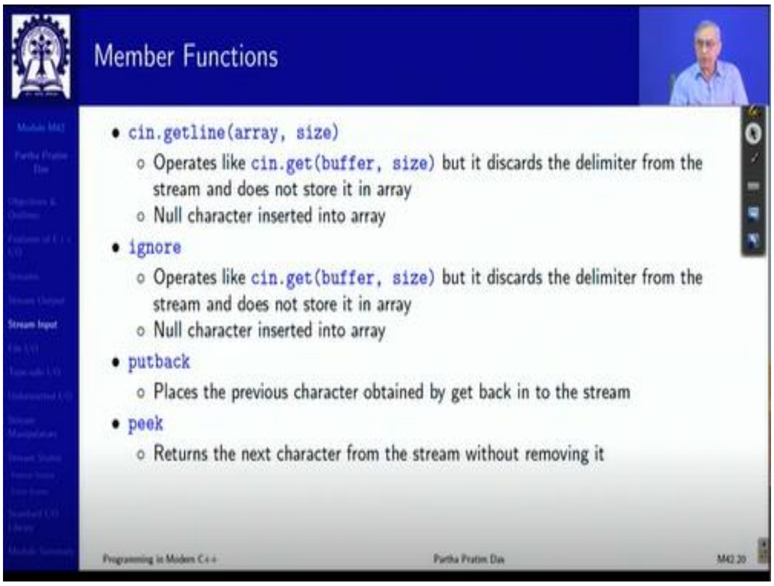

You can read a line by getline, you can ignore some, you can you have read character, you can put it back, you can see what is the character you are about to read without actually removing it from the stream and so on. So, there are number of these functions, you can use them as an when you so, whenever you need to do something just look up, you will find that in I mean almost certainty I can say that it will be available in the standard library in the istream or ostream, ifstream or ofstream for you directly.

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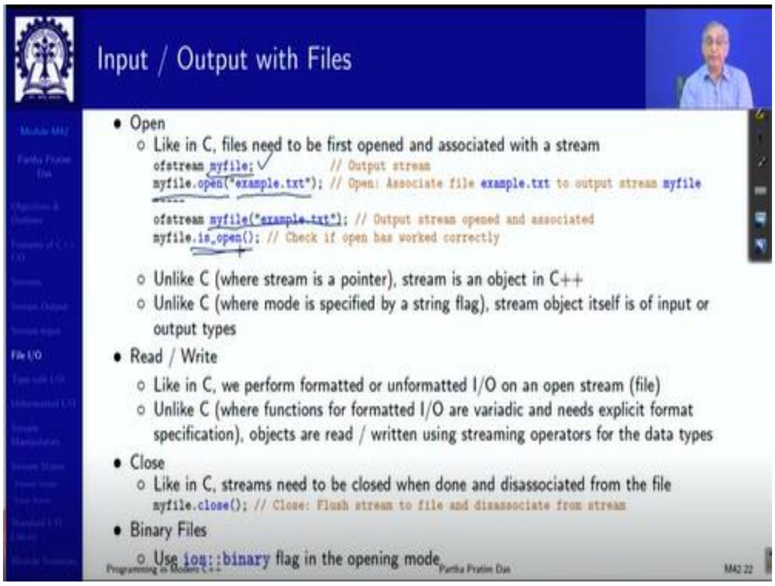

So, now, let me just show you the final total example with working with the file in C++. So, like in C, you need to open the file that is you need to associate the file with the stream. So, if I am trying to do this, say for output, I am showing the example for output. I declare my stream object myfile and that is of type ofstream, output file stream very simple. And then my file has a method open to which I can pass a name.

So, this simply does the association if it cannot, then it will throw an exception. An alternate way of doing that would be to do it at the time of construction itself that is you can make out this construction is happening by default constructed, but ofstream also has a constructor which takes the name of the file as a string. So, you can directly to the opening along with the creation of the stream object. So, this will happen and then you can check if it has been if a file has been open correctly, this will give you a true if it has been opened correctly otherwise false.

So, this makes it really very simple. You do not have to do all these modes and all that in terms of see if you see that the stream was just a file pointer, which did not have any specific type for input or output. So, it is possible that you have multiple file pointers open and you mistakenly use an input file pointer for doing a fprintf or the vice versa these kinds of things will not happen here because your corresponding types are radically different.

So, you do not need to set a mode because this itself tells you the mode. You do not need to say that this is output, because this will itself tell you that this is output if you have to do input, then you have to create a stream which is an object of ifstream class and the mode will be the input one.

So, this is a I mean the clean object-oriented solution. After the opening has been done, that is association of the file and the stream has happened then you keep on using the stream keep on writing or reading whatever you have planned for in the formatted or unformatted manner to that using the streaming operators.

And finally, when you are done then you close. So, like in C we had had the close fclose function which takes the FILE* pointer and closes dissociates here you have the closed member function on the corresponding type of the stream object, and you just invoke that. If you want to specifically open a binary file, then you have a flag ios::binary, which you will have to specify when you are opening the file or you are creating the file as a second parameter, if not specified, it opens it as a text file that is a default behavior.

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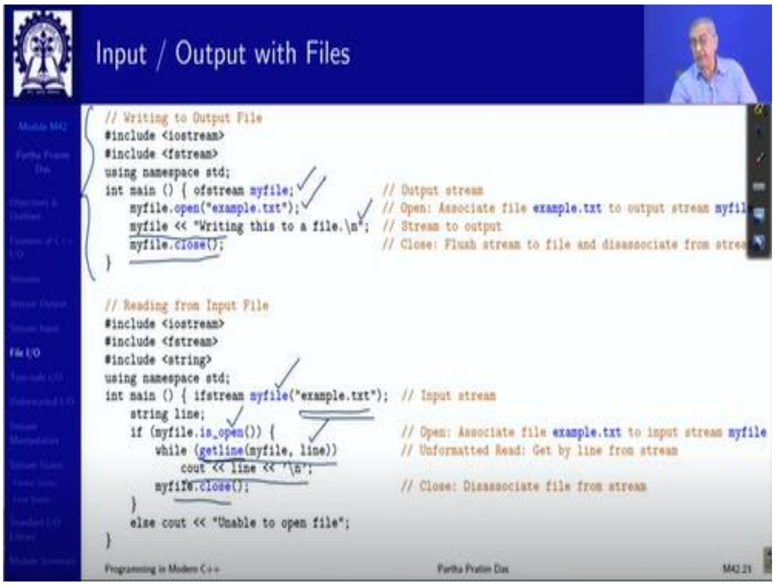

So, here is a small example, actually two examples one is writing to output file. So, I create a default stream object. I open a file and do the association. I do a streaming to it exactly as I do in terms of cout. And that is written to that file, I do a close which will by which the association is broken, and the buffer will be flushed and the file will be closed.

Similarly, here, I am opening a stream with my given file at the construction itself. I check if it is open. If it is open, then I am reading from my file, that is what I have written here, I am reading that and I output that so, I am reading it as a as a line. So, this is a line buffer, I read it as a line buffer and output that to the stdout. When I am done, I close my input file. This is a simple way everything else besides these few lines, everything else is exactly as you did in case of cout or cin.

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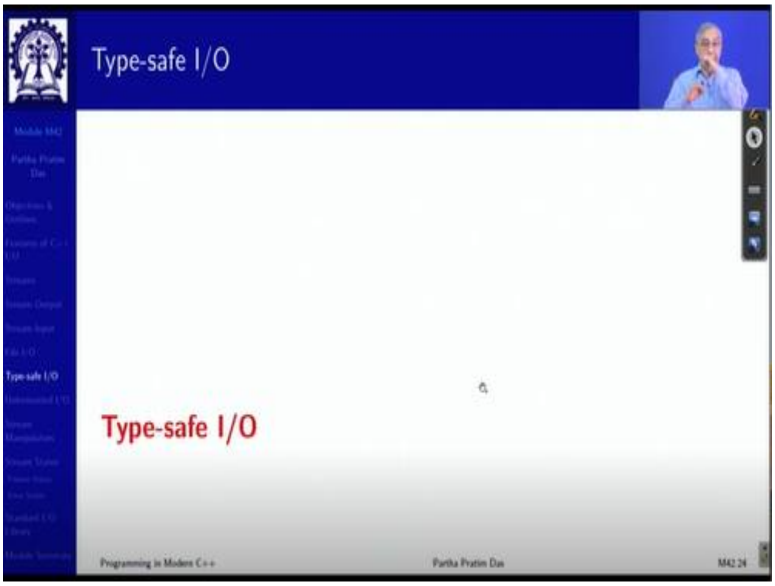

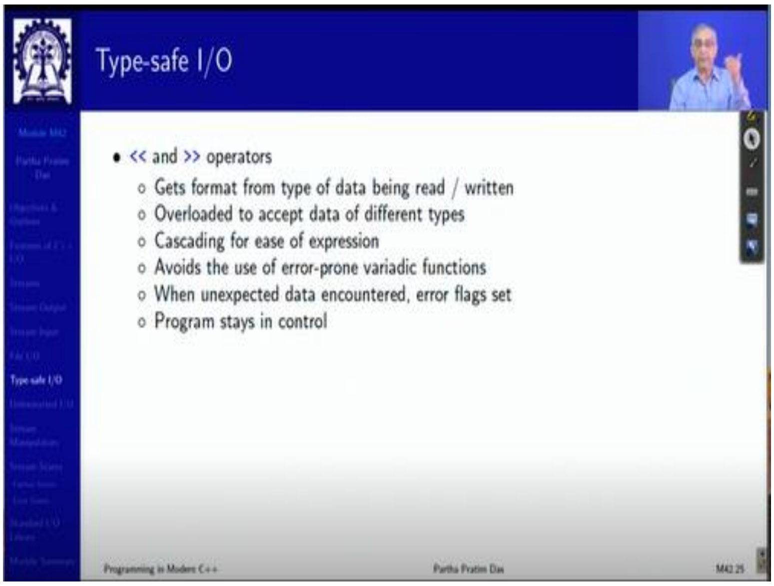

Now, the most critical thing is that the I/O in C++ is type safe that means it is very difficult to make errors in the I/O. It gets the format from the type of the data I have already mentioned, and for all built in types, the overloads of this operators are already given. Cascading makes the ease of expression you do not have to correspond the format with the type of you know data listed you just keep on saying one data after the other it happens automatically. So, it avoids the use of the error-prone variadic that is variable number of argument functions like printf, scanf and so on so, makes it and makes it much easier to use.

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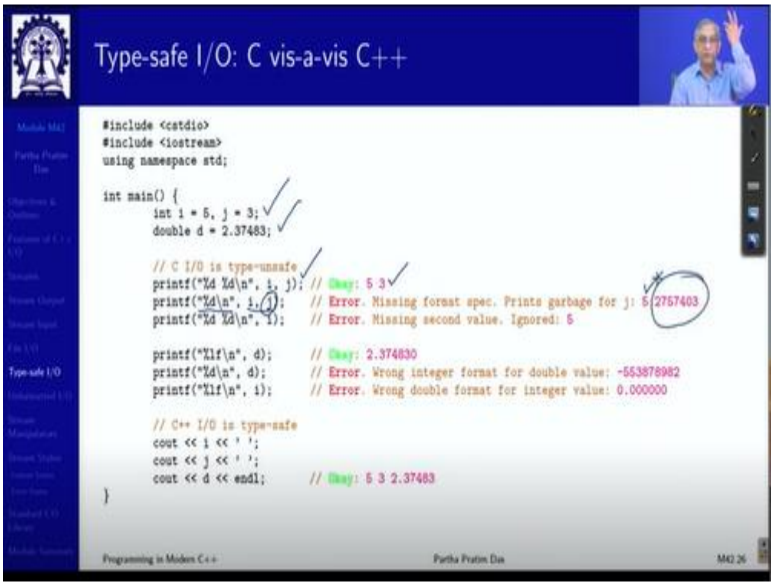

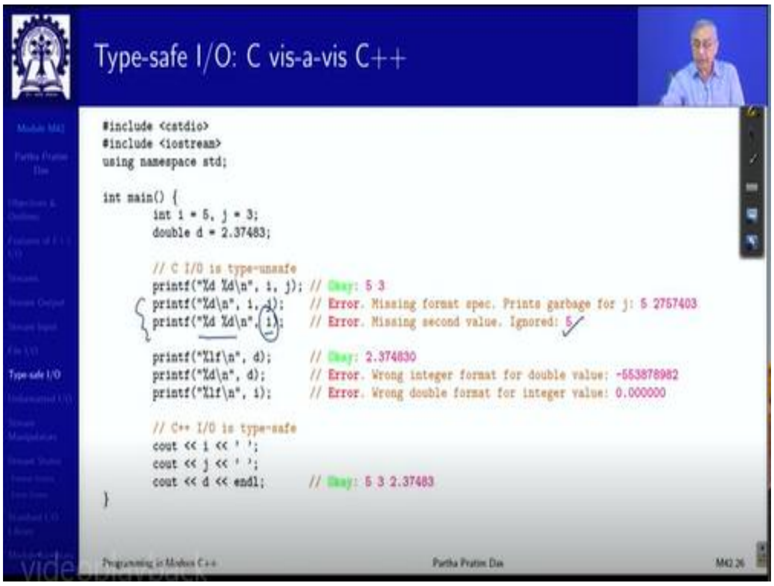

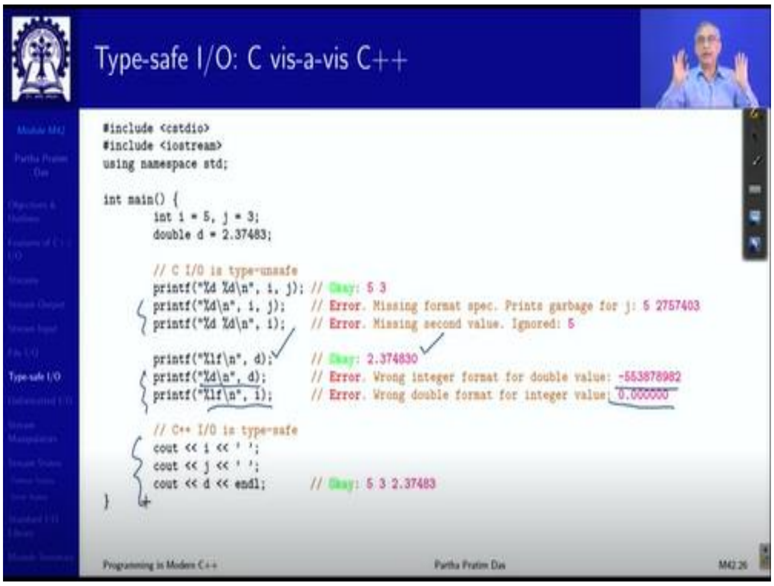

So, here is an example of type safety C versus C++. So, there are two types of two integer variables and one double variable this is what I wanted to write for the integer %d %d it prints okay. Here I have missed out on one %d which can always happen and I write two. So, since it is it is missing and there are two values given it prints the first one it knows the percentage the for the second value j it does not know what is a format. So, it prints in some god knows in what format.

A problem of the reverse kind can also happen for example, you have written two format strings and but given only one input, which will not give you an error or garbage but you will simply ignore. So, %d it has got i it has printed that it does not have a second variable to print. So, it does not do anything. So, all these kinds of errors are possible. What is even more dangerous is if you use the wrong format. You want to write the double value you have to use %lf it prints the value correctly.

Suppose you have done it with d it will not tell you anything it will silently print something. You know what does it printing it is I mean this entire double is interpreted, reinterpreted as if as an int in some way and a negative value is generated. If you happen to do the reverse, you are trying to print an integer but using the format for double %lf you again get something meaningfulness. So, all these errors will keep on happening.

If you do it in the C++ style, there is no scope of error because all these specifying the format the order the matching corresponding correspondence between the position of the format string and the position of the variable all these do not exist. So, you can just keep on cascading and it is guaranteed to work it is safe, type wise it will always work.

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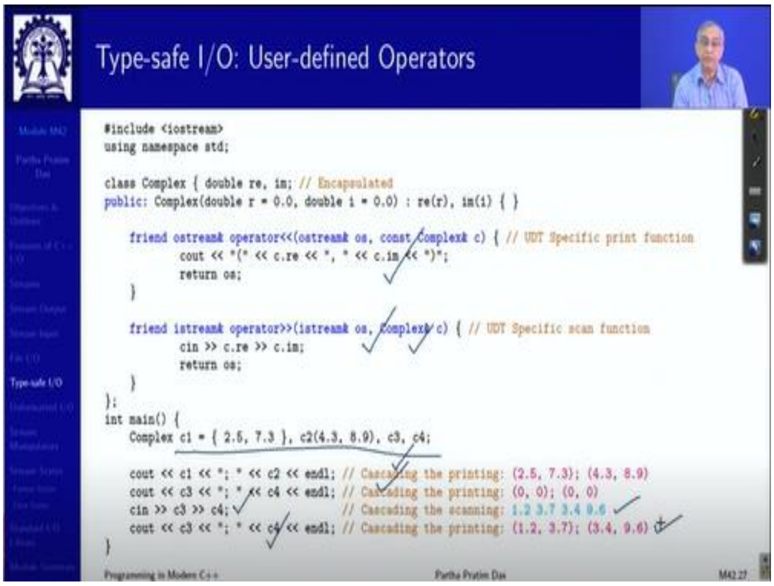

What is more is the type safety extends to user-defined operators this is just for your reminder. So, here is the operator for output is the operator for input which I have defined for the Complex class you have seen this before. And here, we have some Complex class objects which we can cascade and write, cascade and write. Then we can read into them using the read operator and again right to check that you are getting correct values.

This is for completeness, because we have already discussed this, but for completeness in the context of the I/O is very important that it is type safety is not only available for the built in types, but the same safety and the same syntax and the same cascading is available for any user-defined type which makes everything very uniform.

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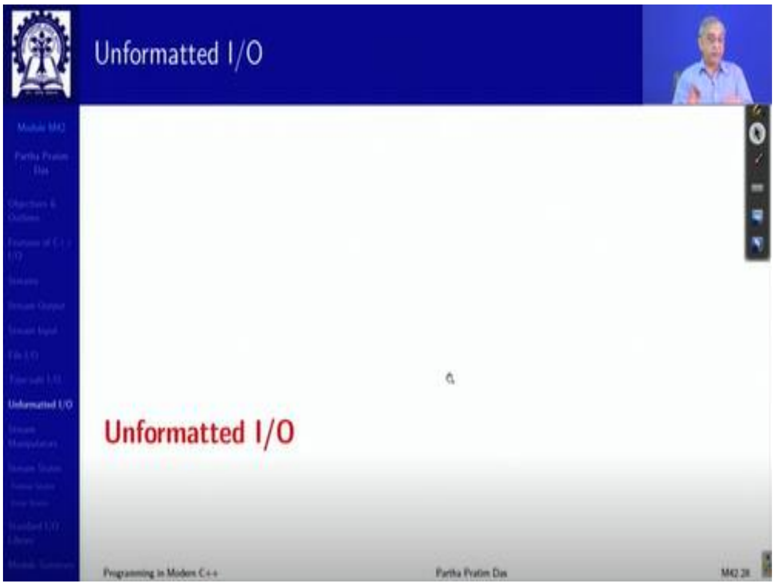

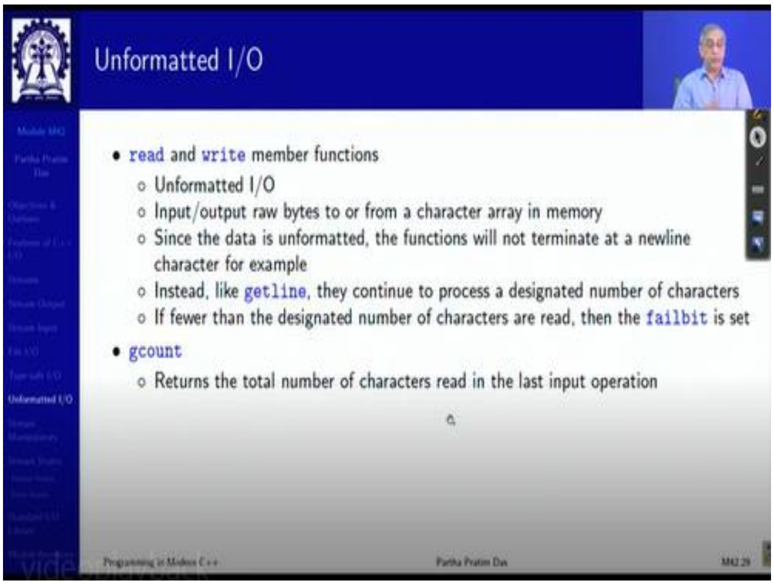

Certainly, you can do unformatted I/O there are member functions like read, write, getline. We have already seen total number of characters that you have done and so on.

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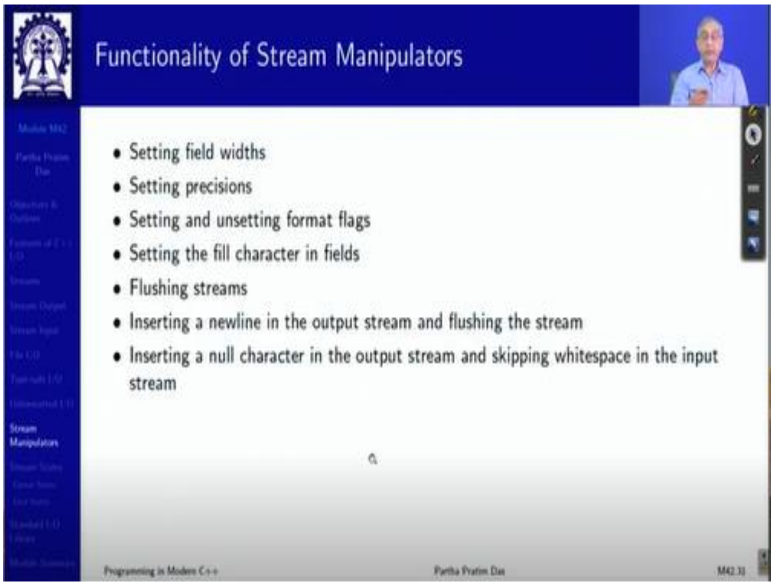

Stream manipulators, we have seen already for example, we have seen how to flush the stream and so, on how to put a new line we already know.

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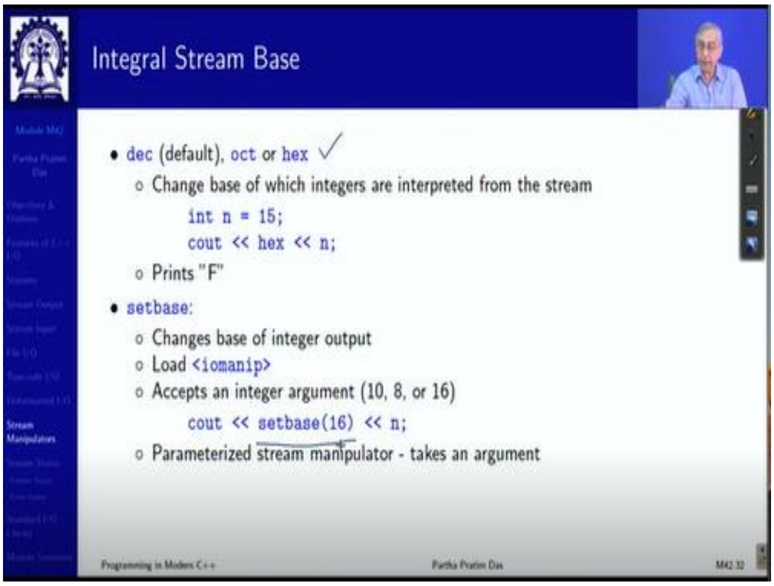

So, these you have seen you can change the base also you can say that I want to print this value in the hexadecimal base and so on.

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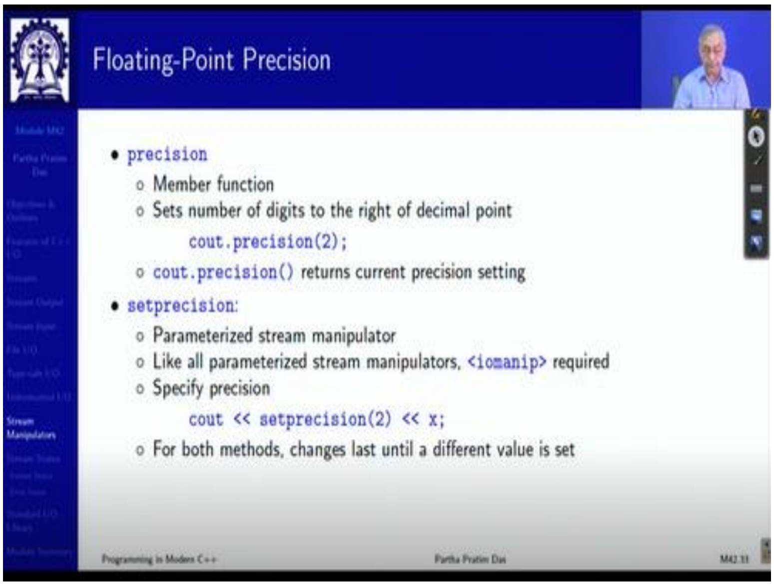

So, there are several manipulators like precision is something which is very-very important because you can buy precision you can say how many points after the decimal that you want. You can clearly say that by invoking the precision member function of cout and then basically stream to it or you can use the setprecision function as well.

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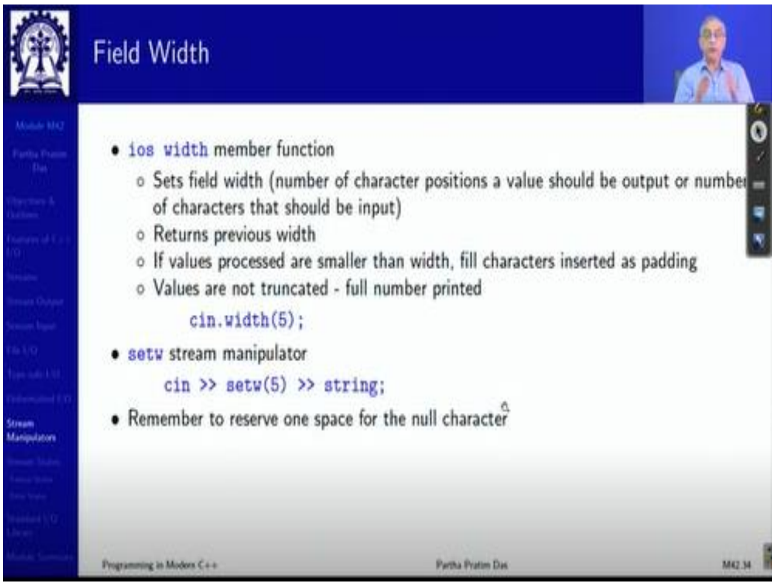

You can control the field width these I mean there are number of them, you just need to I mean whatever you need, you just look up and apply that the style is the same that either you can invoke it as a member function on the stream object or you can invoke it you can have it as a global function wrapper in a iomanip.

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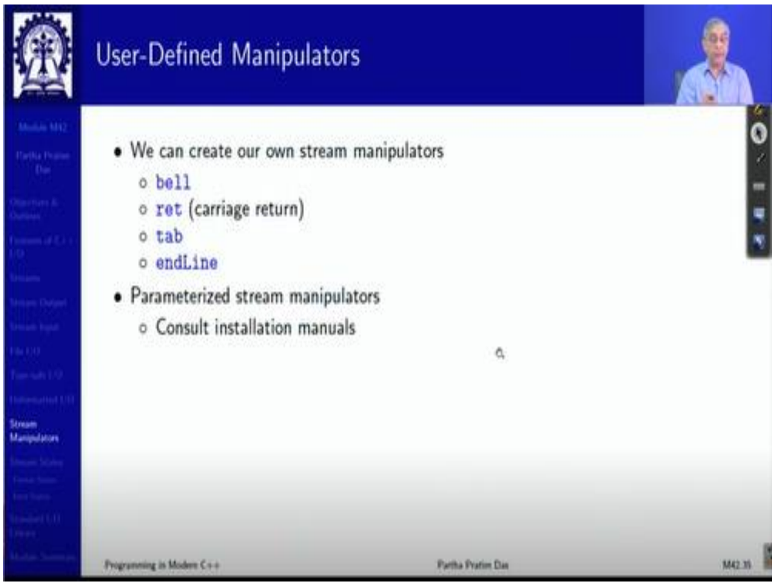

In for all this, you will have to certainly include the iomanip library component.

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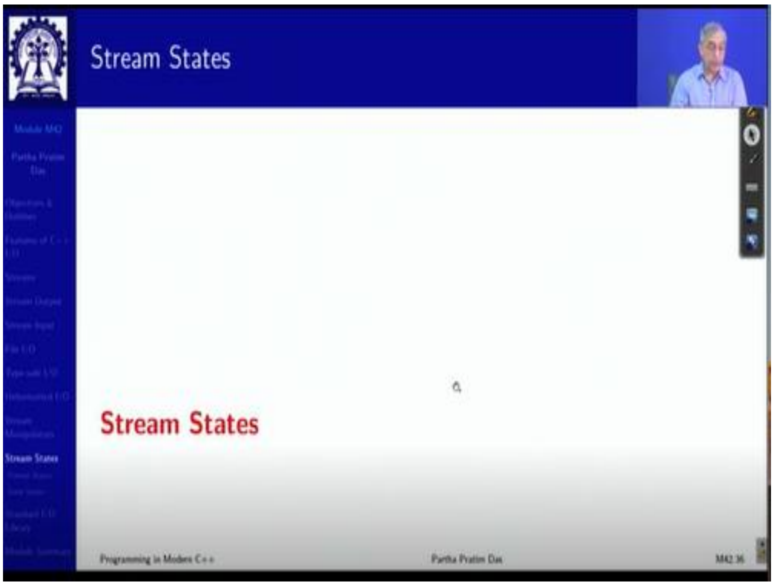

Now, in the next couple of slides, I am not going to go through at all because these are for completeness of information in terms of what are the different states that exist for formats of files, as well as in case of error states. So, those are just like data. So, there is nothing no concept involved particularly. So, you can just look at them and refer to them as and when you need.

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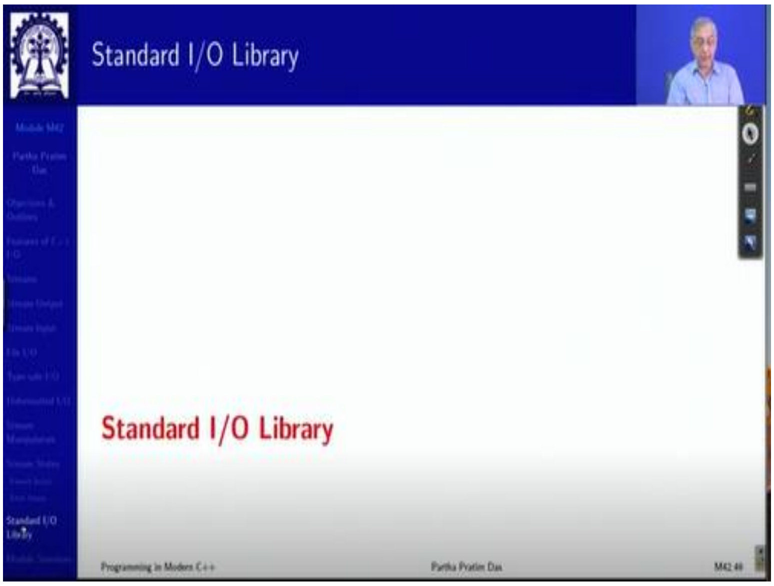

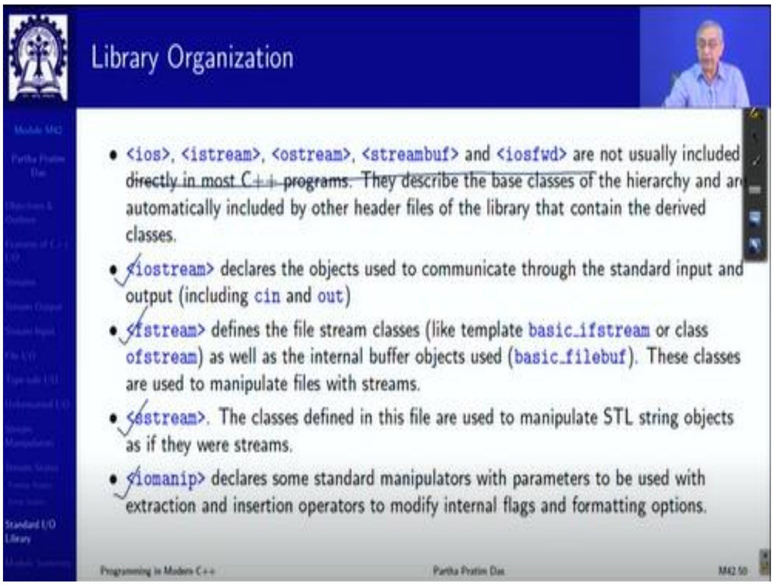

Before I conclude, I will just summarize on the standard I/O library for C++. So, in terms of the organization you can see that what we typically need to include is iostream and sstream if you want to do with strings and fstream or specifically fstream or ofstream. We can do fstream itself like you are doing iostream and iomanip everything else like these all different headers are included through them, you do not directly need to include them, particularly as you do the application programs.

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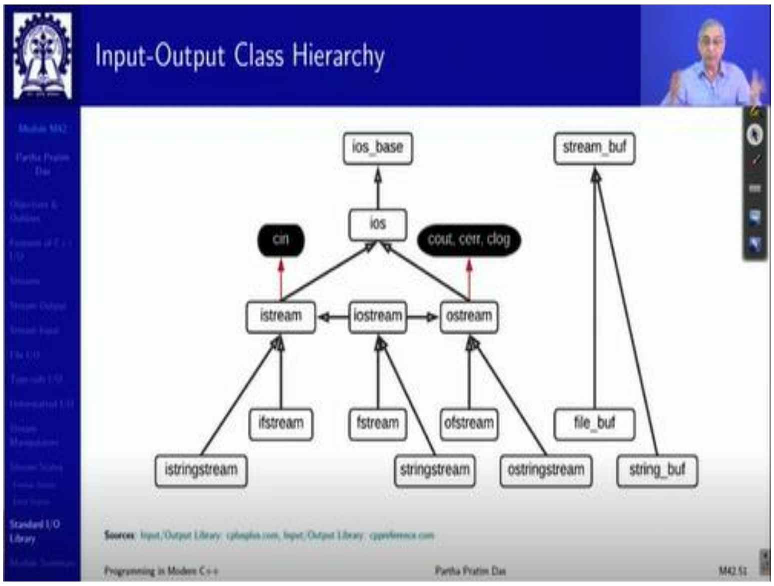

This is the overall class hierarchy for your understanding. So, you can say that ios base is what lies in the stop, but ios is a main implementation of the input-output system from which istream and ostream both are separately inherited and iostream is multiple inherited from both and then fstream and string stream are come from them. So, that is how this whole structure goes on.

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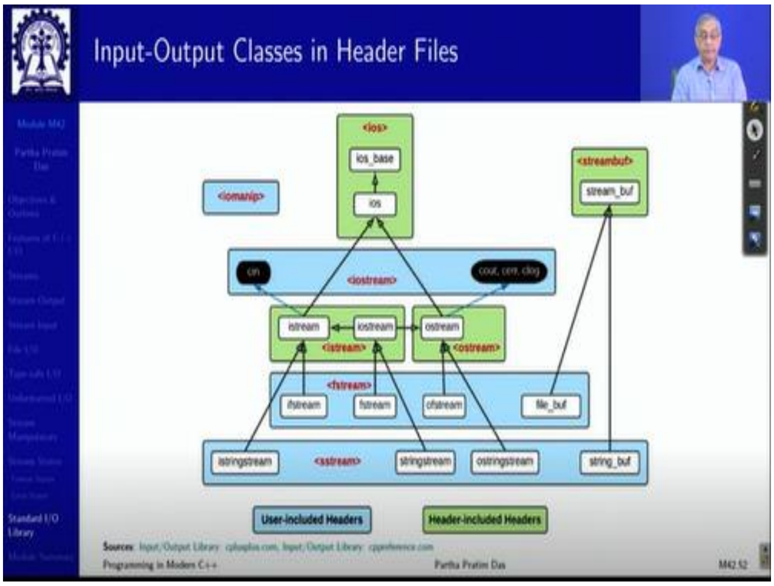

And this is the complete diagram of classes and the different files, remember the blue ones are what you will need to include the four iostream, fstream, sstream, sstream and iomanip others get included as it is.

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And this is an organization of the header for your reference which includes switch header.

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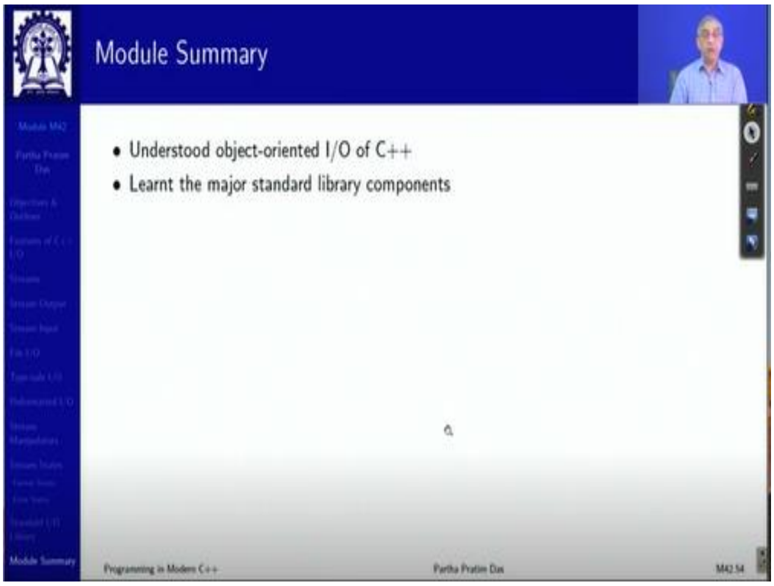

So, we have a kind of taken a look at the object-oriented style of I/O in C++. We have seen how it gives us very compact type safe mechanism which is extendable to user-defined data types. Thank you very much for your attention see you in the next module.