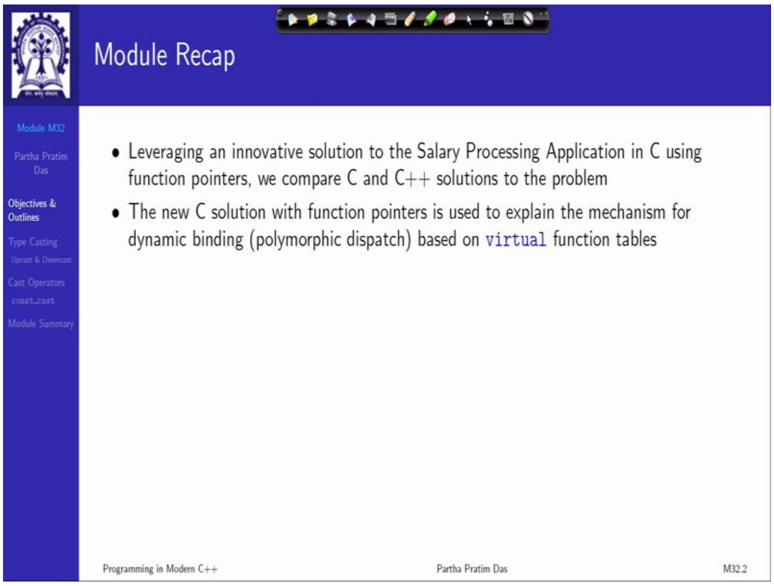
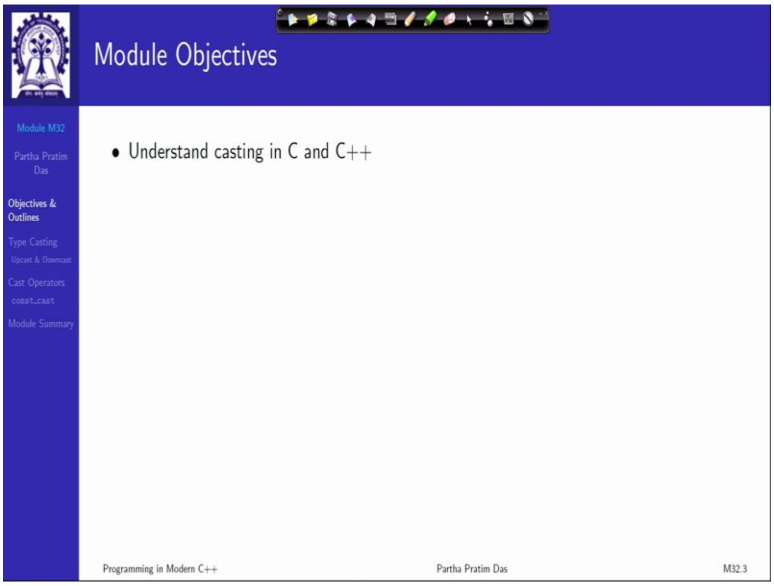
Programming in Modern C++
Professor Partha Pratim Das
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur
Lecture 32
Type Casting & Cast Operators: Part 1

(Refer Slide Time: 0:34)



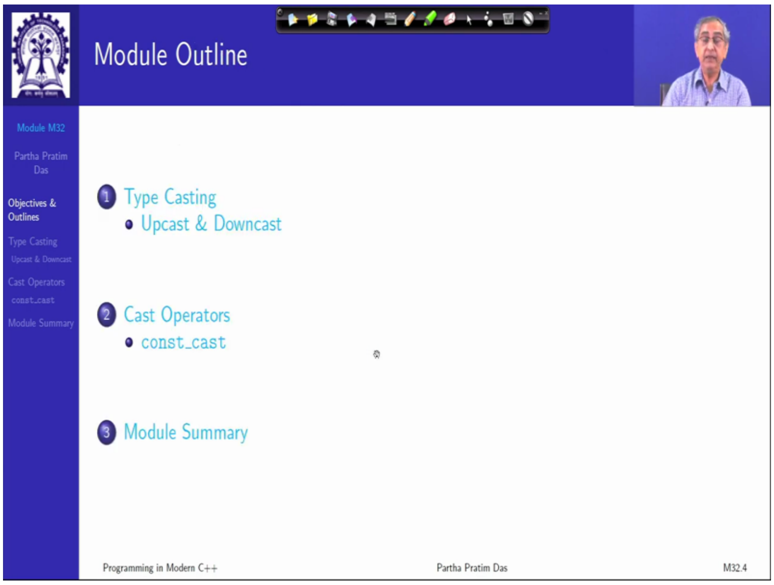
Welcome to Programming in Modern C++. We are in Week 7. And I am going to discuss Module 32. In the last module, we have talked about virtual functions and virtual function table that is an implementation of virtual functions as table of function pointers and how does it parallel with a nearest C application.

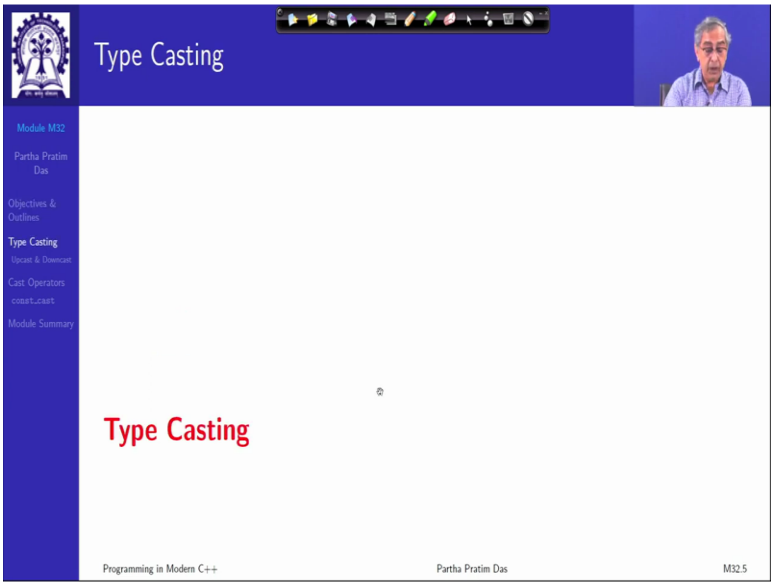
(Refer Slide Time: 0:52)

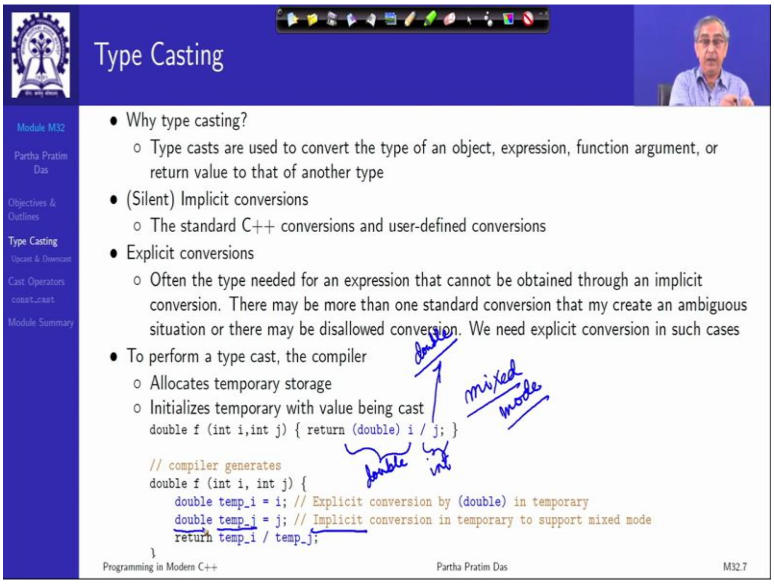


Now, in this module we will go back to discussing the typecasting again. In fact, this will be a 3-part discussion covering this module and next two modules. You recall that in the module 26, we talked about casting and particularly in the context of C. Now, we will try to look at how does casting behave in C++? What is a very very significant difference between typecasting in C and in C++ and how to do it rightly in C++?

(Refer Slide Time: 1:29)







Okay, so this is the sample outline. So, I will start naturally with a quick recap of what we have learned in the earlier modules about casting. So, the first thing we learned is why do we have typecasting? Typecasting is used to convert the type of an object or expression or function argument or return value to another type. And we have seen that we often need this.

We have also seen that compilers often do this silently either because of the way we have written the code or because it needs to put things together which are not of the same type but can be made to be of the same type. And if it does that silently, then it is called the implicit conversion. So, that includes standard C++ conversions. Earlier we talked about C conversion. So, now we are talking about C++. So, we will say C++ conversions. And what will additionally coming which was not there is user-defined conversion.

So, we do not still know what user-defined conversions are. We will come to that. The other that we have seen is explicit conversion where; why do we need explicit conversion? Because often the type needed for an expression cannot be obtained from the given type through an implicit conversion. Why can might that happen? That might happen due to multiple reasons. One it might happen, because suppose, to do this conversion, I need more than one, a chain of implicit conversion.

Now, or there may be two ways to do conversion. Now, if those kinds of things exist, then the compiler feels that it is getting confused. Because suddenly the compiler does not want to assume something which the programmer did not really mean. So, it is much better to refuse to compile that than to compile something which has you know, unpredictable behaviour.

So, the compiler will refuse to do implicit conversion and you will need to explicitly say that I want this conversion to be done. Only then the compiler will do that conversion. And that is the basic notion of explicit conversion. In fact, explicit conversion maybe, maybe put in place in cases where it is not only that standard conversion is not being not unique but it may also happen that it does not exist. It is disallowed but you still want to do it. You will still want to take a pointer and treat it as an integer or treat it as a long. So, that is the reason we need explicit conversion there.

Now, the question is what actually happens in the conversion? Now, when you say conversion, we have kind of a mental set that well, a conversion is like, I have an integer value 2. I convert it to double. It becomes 2.0. I have an integer value 2.0. I am sorry double value 2.0. I treat it as integer, it becomes 2.

It feels like that as if conversion is kind of rewriting. But often that may not be the case. That may be either case. But often that may not be the case. The conversion or casting may involve actually a lot of computation. It may involve compiler generating specific separate code to do this conversion.

I illustrate here with a very simple example that I started the discussion with that is mixed more division. So, here is a function f() which takes two integer variables i and j. What it does? It casts i to double (into double). This is an explicit conversion. Does not do anything with j. Now, how will the compiler deal with it?

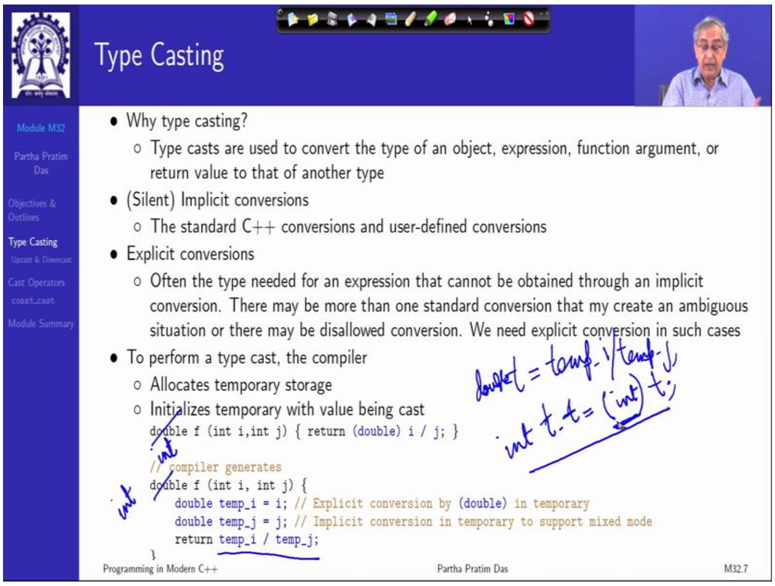
So, the two things. One is there is an explicit cast. Now, obviously the variable i which is storing the value of i is of type integer. It has certain size and certain format to store integer. The value that results by converting it or casting it to double cannot be stored in that location. It does not fit. Does not follow the format. Is not semantically consistent.

So, what the compiler has to do? Compiler has to define a new temporary variable. So, say I mean this may not be the name that the compiler will use but it will use something equivalent. It will as if create a temporary variable of type double which is say temp_i. And take the value of i, rewrite it in the form of a double number, double literal. So, it will do an explicit conversion based on this instruction of explicit double conversion. And temp_i now becomes a double representation of the value carried by i. It may be exactly the same. It may be a little bit different or it may be substantially different. who knows?

Second, what it does? Having seen that it is this part of the expression has a type double. This part of the expression has a type int. In C terms it is mixed mode. In other words, it is being asked to perform a double, a division using a double value and an int value which does not exist. So, it decides to do a promotion. It decides to promote this on to double.

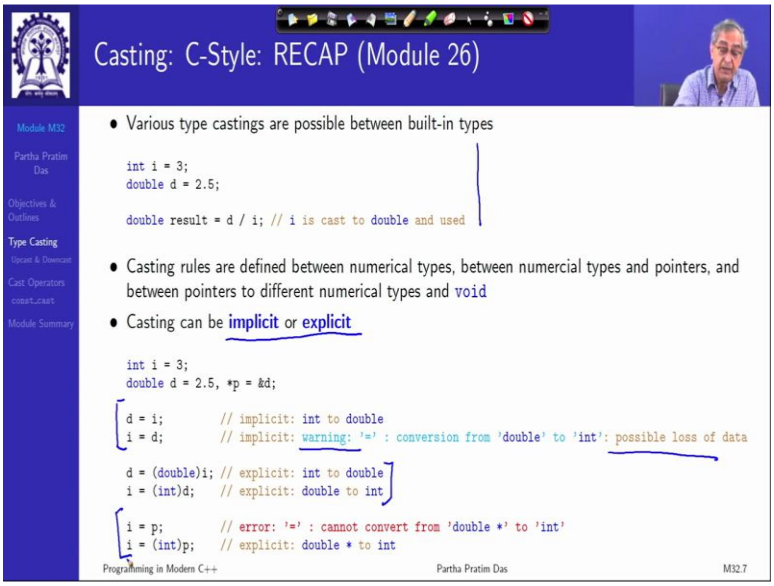
And this promotion is not mandated by an explicit casting to double. So, it has to perform an implicit cast, implicit conversion. But the same game is again involved that it cannot keep that converted value in j. So, it needs another temporary variable. It has another temporary value where it converts and keep that value. Now, it has the original values explicitly converted and implicitly converted, 2 to double temporary variables, temp_i and temp_j. So, it will jolly well go ahead and do a division and return that result.

(Refer Slide Time: 8:25)



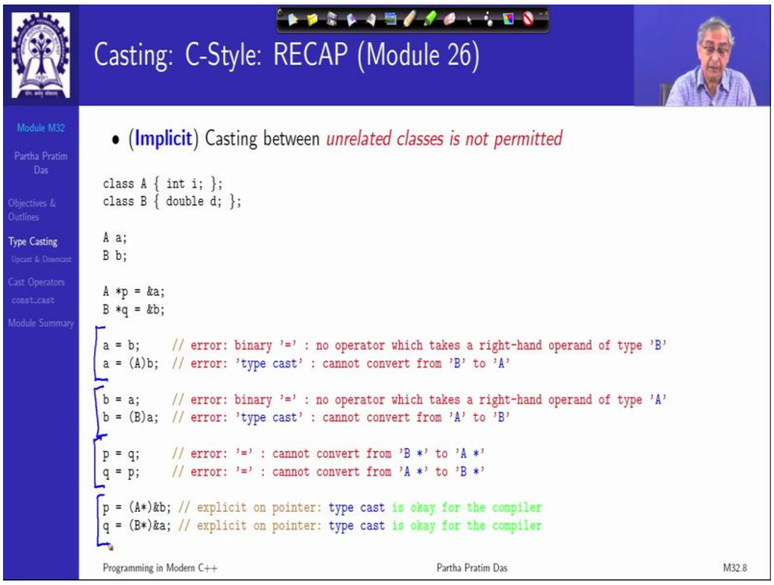
The things would be even more complicated, interesting if instead of return type being double if this were int. If this were int, then this will not work because this will give a double value. So, what would you again have to do? Possibly t gets say double t gets temp_i divided by temp_j. Then it has to do an int t_t which has to take the value of t, internally explicitly cast it to an integer. But to you it will look like implicit because it has to convert; because it has to give you back the int. Some more code will be there. So, my whole idea is to show you that when I do this kind of conversion, actually there may be code that are generated. There may be computations that are generated which are involved and we have to be careful about those.

(Refer Slide Time: 9:21)



So, these are the typical castings we have seen. We have seen that it could be implicit or explicit. Just quickly recapitulating what happens in C which will also most often happen in C++ with some deviations though. So, int can be implicitly cast to double without any complaint. double can be cast to int with warning because there is possible loss of data. If you do explicit everything will be silent. We have seen the comparisons. But with the pointer, the implicit cast of a pointer to an integer will be refused. But explicit cast will be acceptable. We saw nuances of that as well.

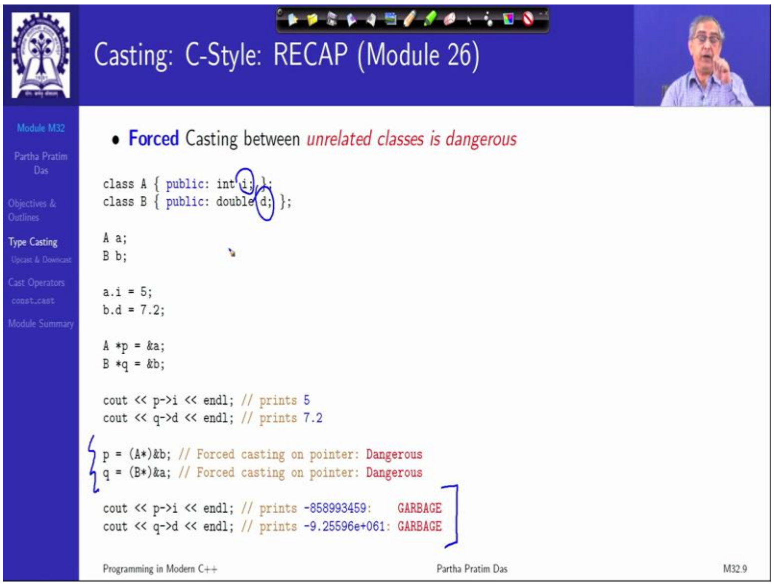
(Refer Slide Time: 10:16)



That was about the built-in types. If we came to the unrelated types, so we saw several things that cannot be done. You cannot convert an object implicitly or explicitly by casting from one type to another. These are none of these are allowed. You cannot convert their pointers implicitly but you can (using the C style) you can explicitly cast the pointer of one type to another type even though they are unrelated. Very dangerous but you can still do it.

We will see refinements of this. The reason I am just brushing up your memory on this is that in coming to C++, we will have finer rules for doing this and finer control of doing this. In C, it was only implicit or you know, C style explicit. Here we will have semantic minute differences coming in.

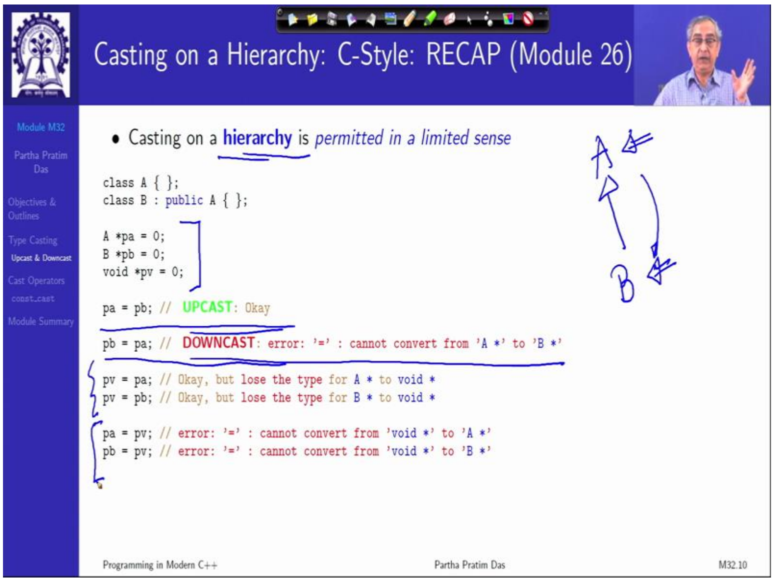
(Refer Slide Time: 11:14)



We also saw that we can do forced casting between unrelated classes as we did here. Forced casting of pointers between two unrelated classes and we saw that what kind of error it could give rise to because one class has an integer and the other class has a double. So, when I cast the pointer of the type of one class into the pointer of type of the other class, then I am actually interpreting an int and trying to print data as a double or otherwise. So, I get all sorts of garbage values. This kind of things will have to be avoided.

And in C++ we will try to you know anything that can that might lead to runtime error, we will try to build mechanisms in casting so that it does not wait up to the runtime error. It can give me the error earlier in compiled time. So, that I do not get surprised because this could be this kind of, you know, erroneous value could be hidden in a lot of deep computation and debugging that would be a practical nightmare. So, I want to avoid that. And that is the reason we are reminding of the places where things can go wrong.

(Refer Slide Time: 12:26)

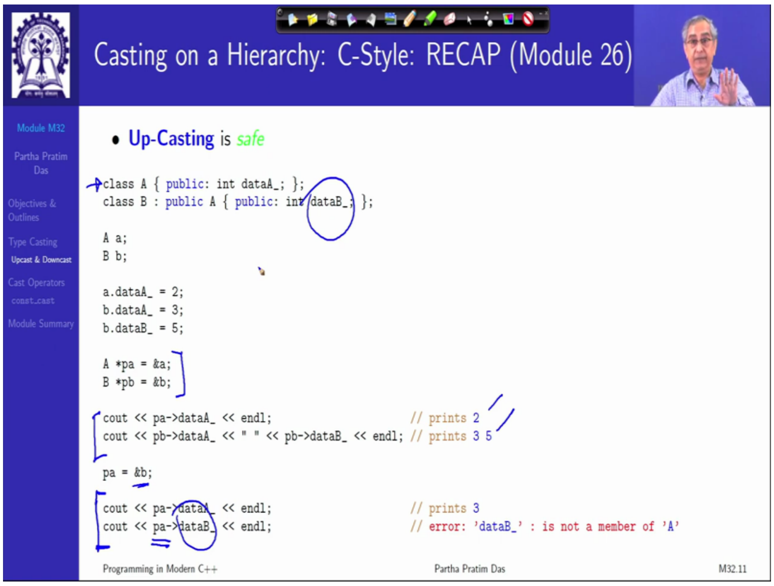


The third type that we had seen are relating to hierarchies. That is when we have an inheritance hierarchy, one class is derived from the other and we saw the pointers of this and we saw upcast is safe. That is at any point of time, I can take a pointer to a more specialized class and assign it to the pointer of a less specialized or more generalized class. That is because specialization keeps on growing the object details or the concept details.

So, if I take if I really have one and treat it as more generalized, then I do not lose information. But if I do the other way around which is downcast. That is trying to take an object of class A and treat it as if as an object of class B, I will have severe consequences. We have seen examples of that reproduced here. So, this is something which will not be implicitly allowed.

With void*, you are saying that is a pointer to I do not know what. I can take any pointer and put it to void* implicitly. I will lose the type information but there is nothing wrong that is going on. But I obviously cannot do the reverse. I cannot take a void* pointer and say that it is a pointer of type A or pointer of type B. Because I certainly I am trying to assume something which the compiler has no way to verify.

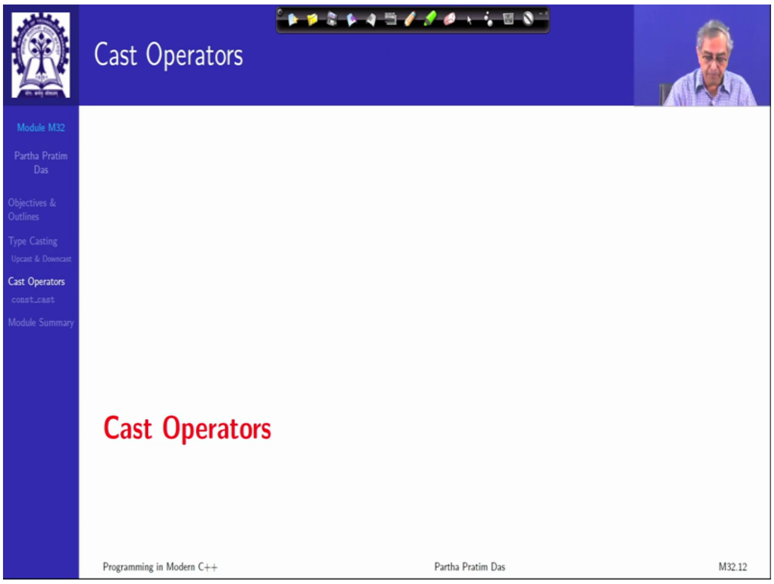
(Refer Slide Time: 14:19)

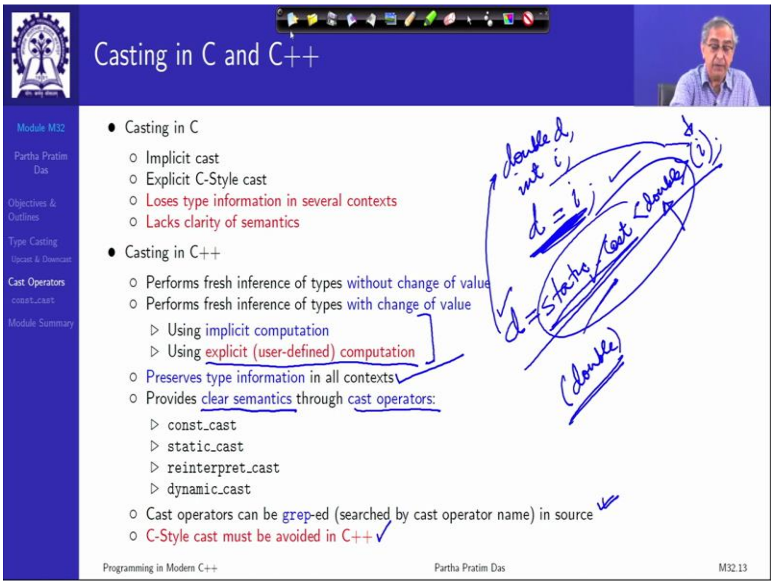


So, this is this is nothing. None of these are new. I am just you know reminding of what you what we did. And we concluded that up-casting is safe. So, with the up-casting, what we have is when we have done the up-casting then if we use the right pointers, we can print everything.

If we are using the up-casting if we are trying to use like pa is pointer to class A, pointer of type class A and holding your object of class B. So, using pa I will never be able to print this data member. I get a compile time error which is fine. So, up-casting always is safe. Down-casting will lead to problems.

(Refer Slide Time: 15:12)





So, that was about again the quick recap of what we have in terms of casting in C++ as inherited from C. Now, C++ deals with casting differently from C. So, in summary, in C we have implicit cast. We have explicit C style casting. We might lose type information in several context and there is complete lack of clarity in terms of the semantics. What do we mean? Everything is, take type one, make it type two is all that we can say. But under what context? Under what context is this treatment of one type as another is valid? C does not allow you to say that.

Now, in C++, firstly what we will have to understand is there is casting which does fresh inference about that object without actually changing anywhere. It is not changing anywhere. But it is just making new inferences about the properties of that object. There are castings of that type.

And of course, there are castings of the original form that we were saying where they actually make fresh inferences with changing the value. So, if you change int to double or double to int, you are making fresh inferences about the type but with change of value. But C++ also allows you to do similar things without changing the value. We will see the example.

Now, this can be done second can be done using implicit conversion or explicit user-defined conversion which we will have to learn. What is user-defined conversion? Does not exist in C, so you do not know. The target is to preserve type information in all contexts. Do not lose the type information. C++ is strongly typed. You cannot lose the type information. So, that is the basic objective.

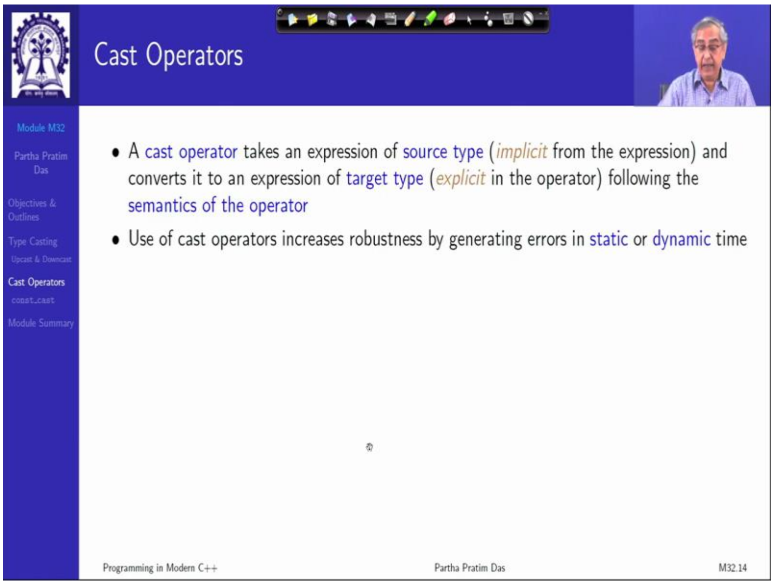
So, with that, C++ provide clear semantics through 4 different cast operators, const_cast, static_cast, reinterpret_cast and dynamic_cast. Now, other than anything else, the big advantage of (you know) using C++ style cast is, they can be searched by the name of the operator. Let me, let me tell you what I what they mean.

Suppose I say I said d. This example we have been using, double d; int i. This is valid in C, implicit. In C++, writing it in the C++ way, I might write this as static_cast. A little bit of writing I agree. But what does it say? It says that take this value i. i is defined as int so you know at this point that it is of type int and cast it to a double value which is possible here because you know that the value of the type of d is double.

Now, what is the difference between these two? In terms of actual computation, there will be no difference. But the core difference is the fact that when you do this, you can search for static_cast<double> in the code. You cannot search for this. There is no textual, you know kind of fingerprint to say that this is where the conversion has happened. It is all implicit. It is all inside. But using this you can get that.

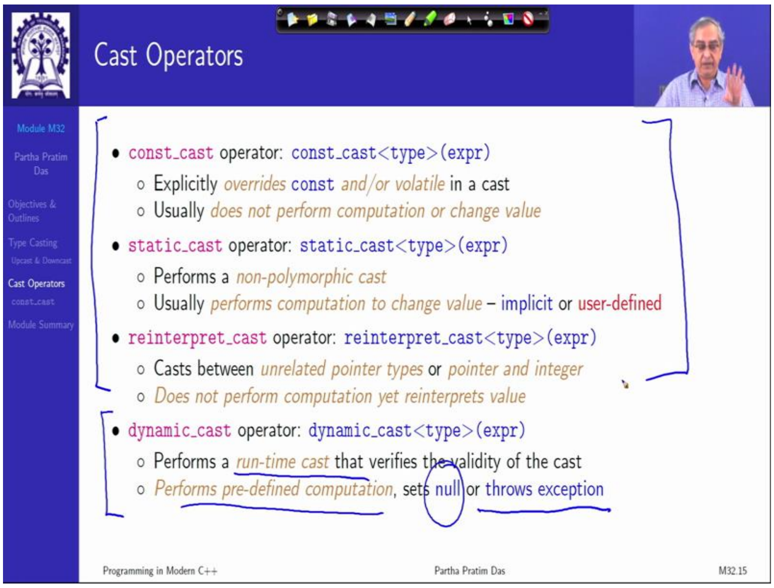
Even it is, it is better than simply writing double because this can happen in multiple different contexts. You do not know in what semantic context you are changing something into double. But here the name of the cast operator will tell you that. Those are the nuances that make the C++ cast operators really great to work with and that is what we are going to learn. Having learned that C++ type, C style; C style of casting must be avoided in C++ altogether. You do not need them.

(Refer Slide Time: 20:09)



Now, how does the cast operator look? You have already seen that. It has a name and is an expression which is the source type. The type of the source expression is not specified because you already know it implicitly and the specification of the target type to which it is going. So, three things as we have seen here, static_cast, this is the name. This is the target type, double and this is the expression i. It could have been an expression i + j * 3. If i, j are integer. I know i + j times 3 is of type int. So, the source type is int. The target type is double and the semantics of the cast is static_cast. This is a basic form of the expression of every cast operator in C++.

(Refer Slide Time: 21:22)



So, we have 4 of them. The const_cast operator; and all 4 of them have the same structure. The name within corner brackets, the target type; within parenthesis, the source expression. The const_cast as the name suggests is to deal with the const-ness or volatility. It kind of overrides the const-ness of the expression that was already there. Like it changes a const expression to a non-const expression and so on.

Static_cast which is the which is a non-polymorphic cast which converts the expression of one type to another type. And there are certain context in which this conversion is allowed. If you try to static_cast in any other context, you get a compilation error which is great. And this static cast could happen implicitly or it can be defined by the user, reinterpret_cast is very interesting. If you cannot cast something, if you cannot cast something by the normal rules rather you should not be doing that cast, then you can still do that cast in many cases using the reinterpret_cast.

For example, you can cast unrelated pointer types. Most importantly you can cast pointer and integer by using reinterpret_cast. As the name suggests, reinterpret. It does not know how to think of as an integer as a pointer? A pointer is an address or a pointer as an integer, the other way. So, you have as if you take the bit pattern and give a new interpretation, reinterpret_cast.

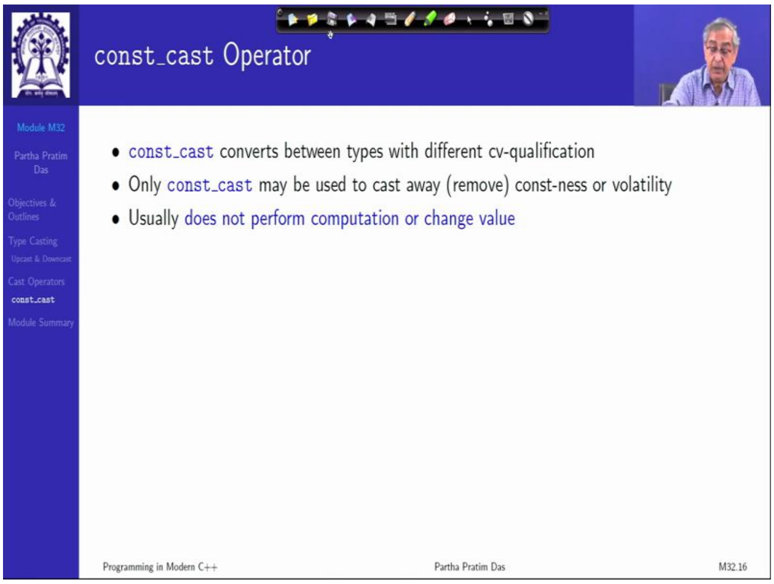
And unlike static_cast it does not perform any computation. So, you can see I said that it could just, casting could just give a different meaning, different inference but not change the value. const_cast does not change value. reinterpret_cast does not change value but gives it a different meaning. Whereas static_cast may actually change value.

The last but the most interesting is a dynamic_cast. All these are compiled time. Whereas, this one is runtime. That is, it performs a runtime casting that verifies whether a casting is valid or not. At runtime you cannot do that because you do not know the actual object. But at the runtime you can do that.

So, dynamic_casting takes an object at the runtime and casts it to some other type, if that casting is valid. And for that, it may do some, it may perform some predefined computation. dynamic_cast is allowed only on pointers and references. So, if you feel the validity of a dynamic_cast, then what the dynamic_cast operator do is, it gives you a null pointer and you know that you have failed.

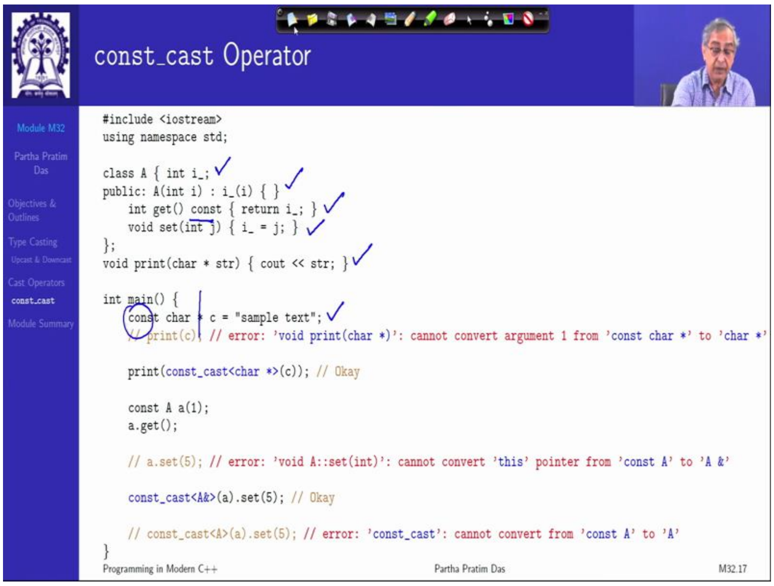
If you have invoked a dynamic_cast on a reference, then it throws an exception because there is no null reference. These are the ways at the runtime to tell you that something wrong has happened. Whereas, for these, if you have unacceptable things going on, conversions going on, then the compiler will give you error. That is the basic summary story of cast operators in C++.

(Refer Slide Time: 25:29)



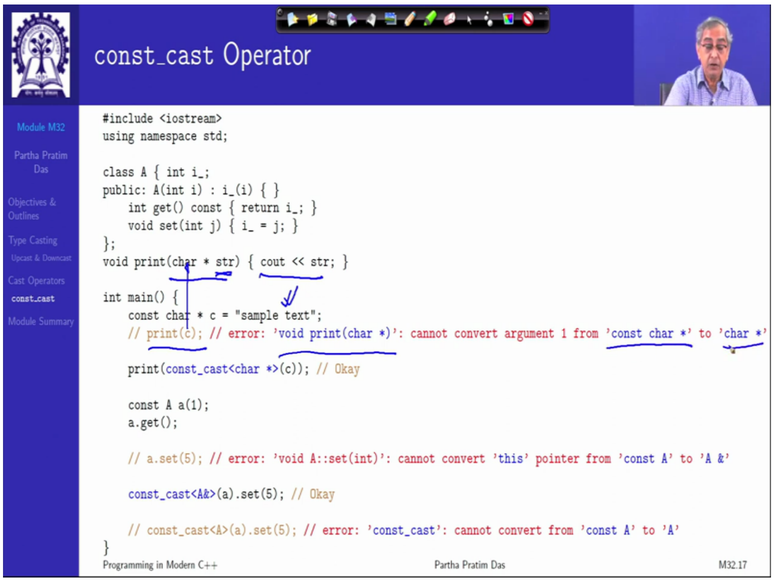
So, having said that, let us talk specifically about const_cast which converts types of different cv-qualification, constvolatile-qualification. And const_cast is the only way to move, I mean remove the const-ness or volatility of certain object. But it usually does not perform any computation or change the value.

(Refer Slide Time: 25:54)



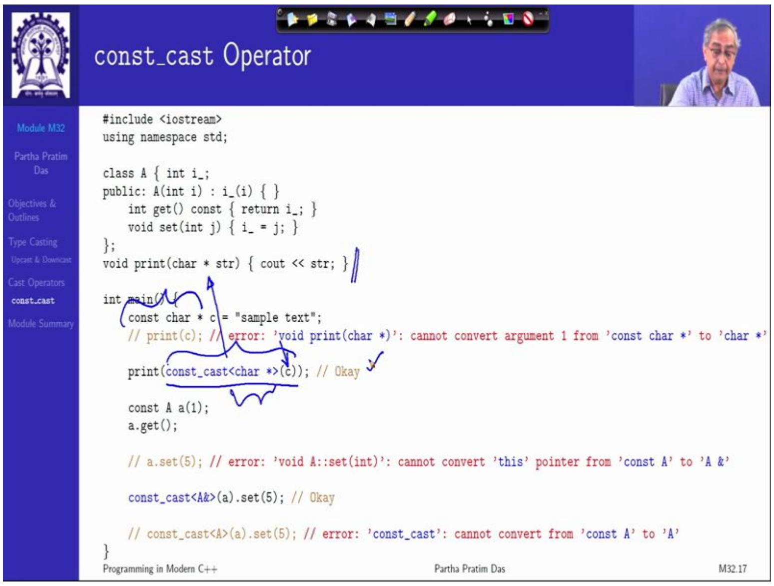
Let us look at an example. So, just here is a class which has a data member i, the constructor. There is a const member function get(), const member function get(). There is a member function set(). So, all that what can you infer from here? You can infer that this const member function can be invoked only on const object whereas the non-const member function can be invoked on const as well as non-const objects. We have seen this. Then I have a global print function. So, here is a pointer to a constant string. This side is constant. So, the pointer to a constant string, so I cannot change the string.

(Refer Slide Time: 26:50)



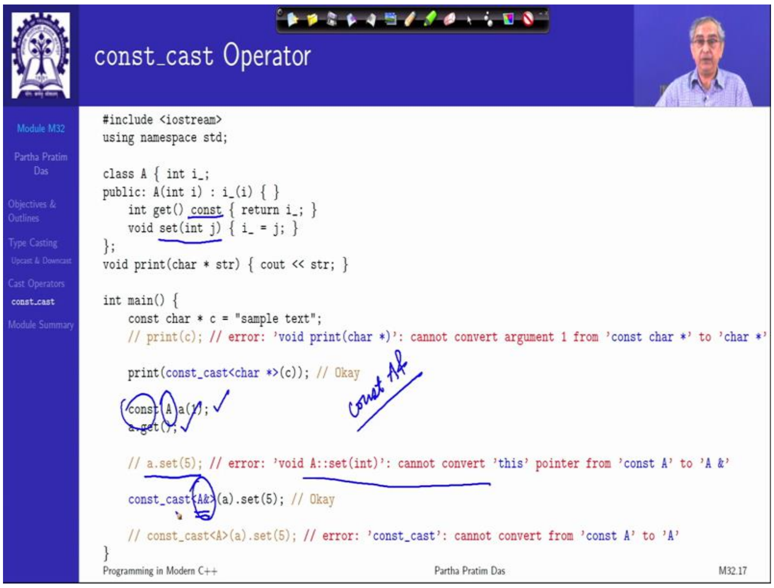
Now, if I try to pass this as print as a parameter to print, I will get an error. Why should I get an error? Because I am passing a pointer to a constant object, constant string to a pointer value where it is a non-constant object. So, what will happen? It is a call by value. So, if I allow this, then this address will be copied here in terms of str. And by changing str, I am not changing it here in this particular case. But the compilers interpretation is by changing str, I can actually change the original string. So, it will not allow me. It will say that the conversion from const char* to char* is not allowed.

(Refer Slide Time: 27:45)



So, the question is, if I have that, how do I call that function? Now, I know from the manual of this library, from the documentation of this library that, this print function does not do any harm to the string which is passed. So, it is okay to pass a constant string. So, what I do I stripped the const-ness. What was the type? It was const char*. So, the source type of C is const char*. What is the target type? I have given char*. So, the const is gone. So, the resultant expression is only char* which matches the formal parameter type of print and everything is okay. That is the basic purpose.

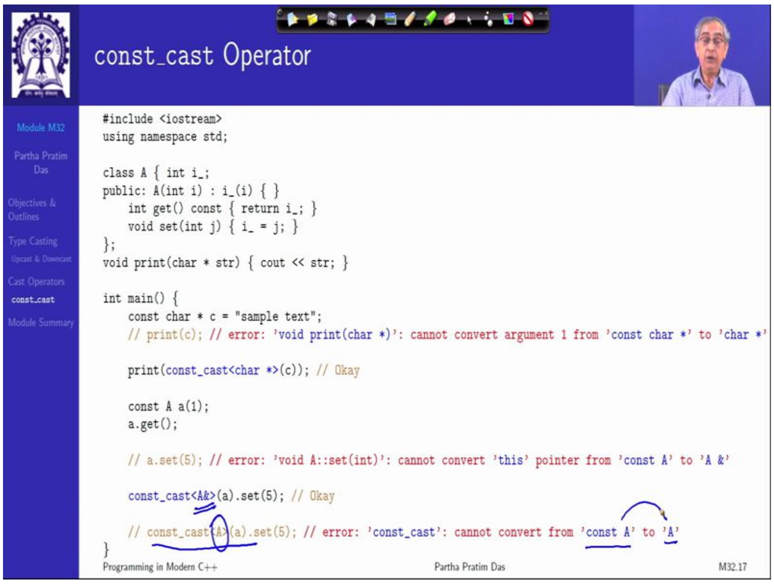
(Refer Slide Time: 28:38)



Suppose I have defined a constant object a. I do a.get. That will work because it is a const member function. If I do a.set, it will give me an error. It is supposed to because set is a non-constant member function. It can change my object. So, validly I will get an error. But if I want to force that well, it may be the case but I want this non-const member function to be called. What I need to do? I need to take away the const-ness. So, what I do? I this object is const A. So, its type is const A&.

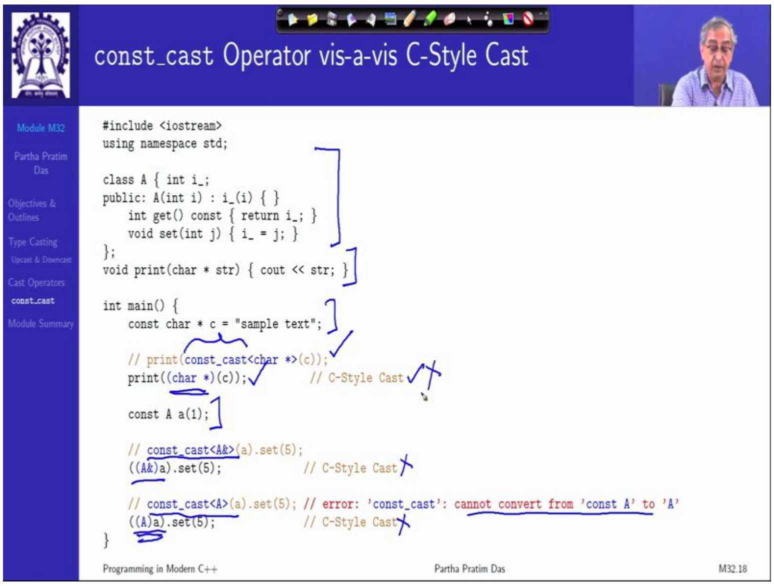
So, what I do is? I take away that const and I just give a target type which is A& which makes it a non-constant object. That is - it takes away the const, the fact that this pointer was pointing to a constant A object. It can now point to a non-constant A object and therefore calling a set is perfectly.

(Refer Slide Time: 29:58)



Mind you cannot do this. You cannot do this. You cannot convert const A to A. That is not allowed because that will mean changing the object. When you are doing A&, all that you are doing you are actually temporally creating another reference which is a non-constant reference which is allowing you to go through the call. But you cannot inherently change the object. So, it is not necessarily that the cast operators will also always succeed. This is a compilation error.

(Refer Slide Time: 30:36)



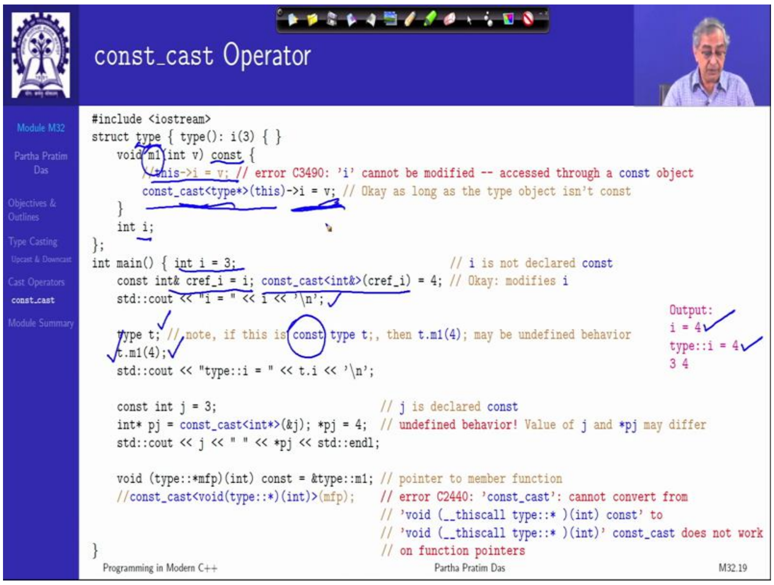
Now, look carefully. We want to; the same example. Here nothing changed. Nothing changed. Nothing changed. Nothing changed. Nothing changed. Now, all that we are showing is what happens with the C-style cast. If I do this instead, I can do this. This will work. C-style casting. Just force it without saying what you are doing.

So, you are missing out on two things. So, you are missing out on two things. One is, as I said it is not easy to find out where the casting has happened. Your char* could be everywhere. Second, even if you find out you do not know what you are casting away. Are you converting c which was an object type into char* or something else. This clearly tells you that you are ripping off the const-ness of the pointer. Nothing else. So, makes good sense but C-style cast will force this.

You could do this as you saw. You can C-style, you can do this. Again, the same complain that finding out A& and knowing that there is a casting is difficult. And second, you do not know the meaning for which it is done. The third dangerous part is, this is semantically not allowed. But if you do it in C, it will allow you. C-style will allow it. So, you can see that there is not only type conversion but there is a semantic difference between C looks at it and C++ looks at it. C++ is lot more strict.

Say if an object is constant, it is constant. You can not make it non-constant. You can have a different reference to it which treat it as a non-constant. Invoking function. You could have a pointer that treats it that way. But the object by itself does not become non-constant which C, using C-style will violate. That is so it is a disaster. Basic recommendation: do not use any one of these.

(Refer Slide Time: 32:47)

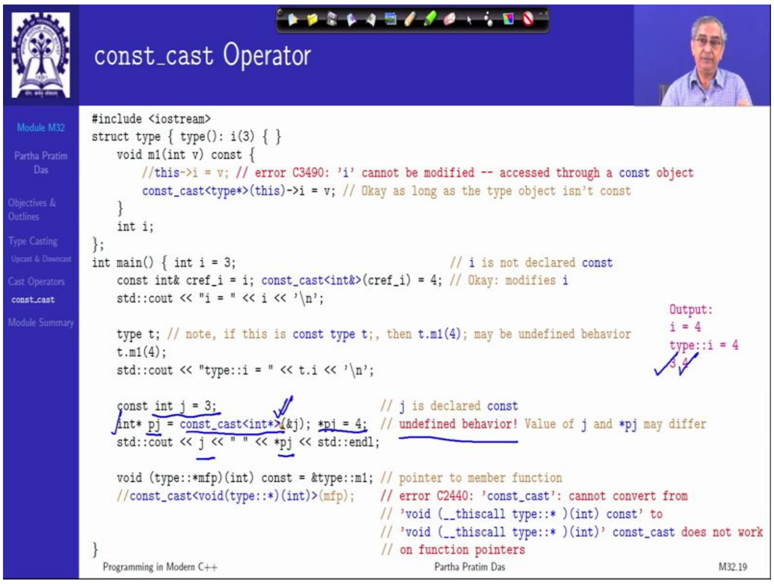


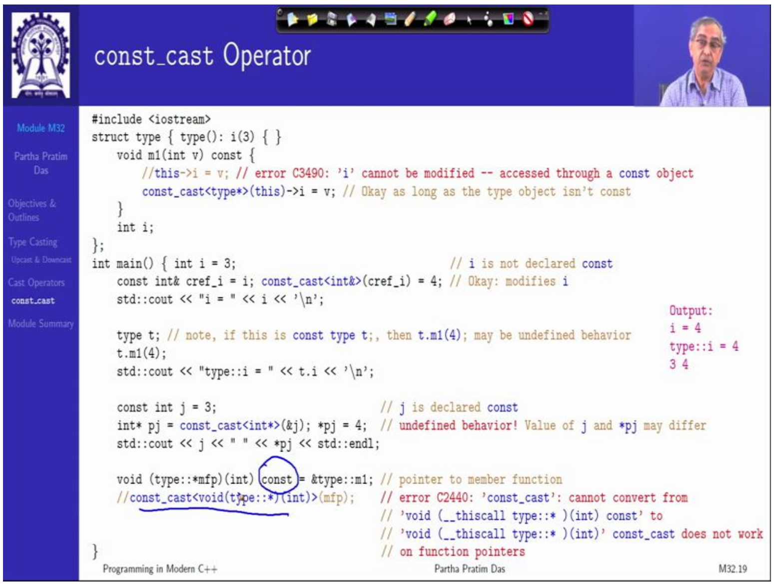
Finally, here there are some more example for you to understand. Here is a struct type, a constant member function. If you have a constant member function, naturally do can not do it, do this in it because using this pointer you cannot change i. So, you cannot do that. But you can strip off the const-ness of the this pointer and do this. So, you can force that by stripping off the const-ness here.

Here is an integer variable and a constant reference to that. You cannot certainly assign anything to this cref_i but you can strip off the const-ness of the reference and make an assignment to it. If you will print, you will get the value 4. You have a type t object. You can invoke t.m1. m1 is the const member function. So, non-const object can always call const member function. If you do that, it will get changed to 4 and 4 will be printed.

Mind you. If you have type t as const, then also you will be able to invoke this. t is const. On a const object you can always do non-const, you can always invoke const member function. But if you invoke that, then the results will be unpredictable. Because you have a constant object by definition and you are forcibly changed something inside. Do not do that. Use the path of mutable and all those.

(Refer Slide Time: 34:41)

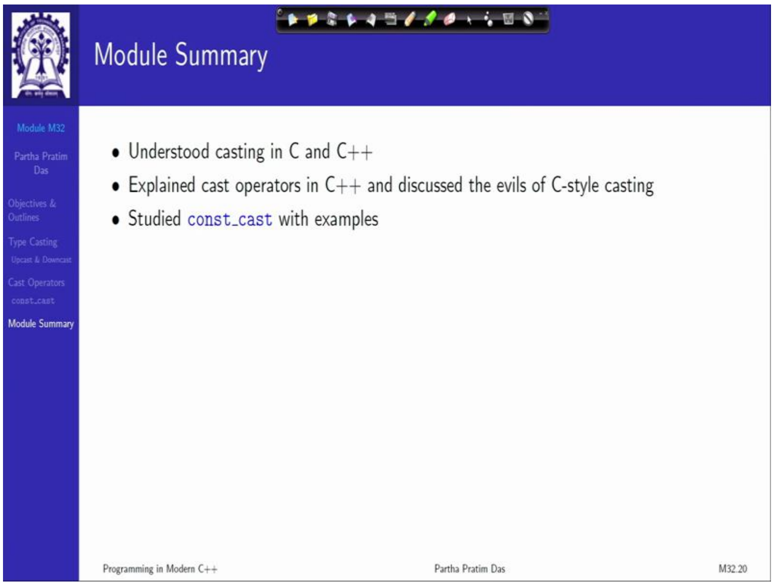




Similarly, we have here. These are just different examples of const-ness. Here is a const variable j and I have created a pointer stripping off the const-ness. So, looking from this pointer it is; so I can now change this. Now, the interesting thing is, pj points to j but j and pj and not the same values. Print j and pj. This j remains to be 3; pj is 4. So, that is what I was meaning. You cannot change the const-ness of the object. You can have a non-const view of the object created by putting this separate reference or pointer.

And this can be risky. This is an undefined behaviour. Your basic assumption that the pointer and the object it points to are same is destroyed. Why does that happen? Because to be able to do this, compiler creates a temporary to put the value of i and let pj point to it. And it is making changes to that temporary, not to your j. Very risky. Here is one more example with function pointer. You can see that even with casting, const_cast, you cannot change the constant member function to a non-constant member function. Simply because const_cast is not allowed to work on the function pointers.

(Refer Slide Time: 36:15)



So, these were the basic high points about the const_cast. To summarise, we have understood casting in C and C++. I am trying to bring out the different nuances and differences. And having seen the summary of different C++ operators, we have just studied const_cast with examples. And thank you very much for your attention. In the next module we will talk about the other cast operators.