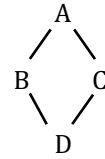


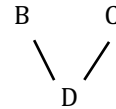
The diamond problem: multiple inheritance

Google “diamond problem” and you will get a bunch of websites that talk about the diamond problem in OO languages, showing a diamond like that drawn to the right. It shows classes or interfaces (Java terminology) A, B, C, and D, with (1) B and C extending or implementing A and (2) D extending or implementing both B and C. The diamond problem has to do with multiple inheritance. If both B and C declare a method *m* and D calls *m*, which method *m* should be called, the one in B or the one in C? This question has to be answered in some unambiguous way.



Multiple inheritance is an issue not just in Java but in many OO languages like C++, Common Lisp, C#, Eiffel, Go, OCaml, Perl, Python, Ruby, and Scala. Each OO language solves the ambiguity in some way.

We show you the solution to the diamond problem in Java, talking a bit about its history. But in Java, at least, it's not a *diamond* problem, it's a *Vee* problem. Class or interface A is a red herring, it has nothing to do with the problem and can be removed from the discussion. Only B, C, and D are needed to explain the problem and its solutions.



Here is how Java handles the multiple inheritance problem.

1. B, C, and D are classes

The program to the right is not a legal Java program because class D may extend only one class, and here it extends both B and C. But if it were legal, it would be ambiguous because in class D, it is not known which method *m* to call, the one inherited from class B or the one inherited from class C. Java avoided the multiple inheritance problem for classes by allowing a class to extend only one other class.

```
class B { int m() {return 0;} }
class C { int m() {return 1;} }
class D extends B, C {
    void p() {System.out.println(m());}
} // not legal Java
```

2. B, C are interfaces and D is a class, in version 7 or less

Class D can implement many interfaces. To the right, it implements both B and C. Further, in Java 7 and earlier, all methods in an interface were abstract, and method had to be overridden in any class that implements the interface. The interface defines only the *syntax* of calls on a method, so there is no ambiguity.

```
interface B { int m(); }
interface C { int m(); }
class D implements B, C {
    void p() {System.out.println(m());}
    public int m() {return 5;}
} // legal Java
```

3. B and D are classes and C is an interface, in version 7 or less

To the right, class B declares method *m* and interface C declares abstract *m*. Since D inherits *m* from B, D need not declare *m* again; it is already available. There is no ambiguity here because interface C defines only the syntax of calls on *m*.

Suppose B does not declare *m* to be public. Then there is a syntax error: inherited method *m* cannot hide public abstract method *m* in C. There is a choice here: either have *m* in B be public or declare public method *m* in D.

```
class B { public int m() {return 0;} }
interface C { int m(); }
class D extends B implements C {
    void p() {System.out.println(m());}
}
```

4. Default methods in interface in Java version 8

Version 8 of Java, released in Spring 2014, allowed default methods in interfaces, as shown to the right. Since interface C has a default method *m*, class D does not have to override *m*; if it doesn't, the default method is used.

```
interface C { default int m() {return 1;}}
class D implements C {
    void p() {System.out.println(m());}
}
```

Ah, but now we have a problem. With the classes and interfaces shown to the right, what method *m* will be called in method *D.p*? The one in class B or the one in interface C?

For backward compatibility —every version 7 Java program should run in Java 8— the designers of Java ruled that the method in B should be called: the superclass has precedence over the inter-

```
class B { public int m() {return 0;} }
interface C { default int m() {return 1;}}
class D extends B implements C {
    void p() {System.out.println(m());}
}
```

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face.

But what if, in method `D.p`, one wants to call default method `C.m`? Use something you may not have seen before. You can use `C.super`... to designate the implemented interface `C` whose method is to be called

```
C.super.m();
```

In the above, there is no ambiguity. In method `p`, a call `m()` call method `m` in class `B`, and a call `C.super.m()` calls default method `m` in interface `C`.

But if class `D` does not extend a class and implements two interfaces that both have a default method `m`, as shown to the right, the program has a syntax error and won't compile. Even if method `m` in one of the interfaces is made abstract, it's still a syntax error.

```
class B { public int m() {return 0;} }
interface C { default int m() {return 1;}}
class D extends B implements C {
    void p() {
        System.out.println(C.super.m());
    }
}
```

```
interface C1 { default int m() {return 1;}}
interface C2 { default int m() {return 2;}}
class D implements C1, C2 {
    ...
}
// syntax error: won't compile
```

Example of backward compatibility

We said earlier that the choice of a method in the superclass instead of the default method in the interface was made to maintain backward compatibility. Here's one of many examples of why this choice was made. In Java 7, interface `java.util.List` had no abstract method to sort a list. In Java 8, they wanted to make life easier for many programmers by adding this default method to interface `List`:

```
default void sort(Comparator<? super E> c)
```

It can be used to sort any `List`. For the version 7 program shown on the right to work, `B.sort` had to be called from method `p`, even though `List` has the default method `sort`.

```
class B {
    ...
    public void sort(...) {...}
    ...
}
class D extends B implements List {
    void p() {... sort(...); ... }
}
```

About the diamond problem

In the classes to the right, we have the usual *Vee*: as shown near the top of the previous page: `D` implements `B` and `C`. Abstract method `B.p` is automatically public, but `D` overrides it with default modifier `package`, and that is a syntax error. The error that the Java compiler displays is this:

```
interface B { void p(); }
interface C {}
class D implements B, C {
    void p() {}
}
```

Multiple markers at this line

- implements diamondProblem.B.p
- Cannot reduce the visibility of the inherited method from B

Note that it mentions the “diamond problem”! Where is the diamond? Well, interfaces `B` and `C` automatically extend `Object`, so there *is* a diamond.

In fact, we get exactly the same error message for the box to the right, in which `B` and `C` extend `A`. Here, there is an explicit diamond. But we fail to see why this is a “diamond problem”. The problem is only that the visibility of inherited method `B.p` has been changed, and if we change `D.p` to be `public`, there is no syntax error.

```
interface A {}
interface B extends A { void p(); }
interface C extends A {}
class D implements B, C {
    void p() {}
}
```