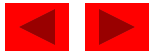
Chapter 9 - Inheritance

Outline

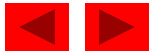
9.1 Introduction

- Inheritance
  - New classes created from existing classes
  - Absorb attributes and behaviors
  - Derived class
    - Class that inherits data members and member functions from a previously defined base class
  - Single inheritance
    - Class inherits from one base class
  - Multiple inheritance
    - Class inherits from multiple base classes
  - Types of inheritance
    - public: Derived objects are accessible by the base class objects
    - private: Derived objects are inaccessible by the base class
    - protected: Derived classes and friends can access protected members of the base class



9.1 Introduction

- Polymorphism
  - Write programs in a general fashion
  - Handle a wide variety of existing (and unspecified) related classes



9.2 Inheritance: Base and Derived Classes

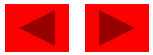
- Base and derived classes
  - Often an object from a derived class (subclass) is also an object of a base class (superclass)
    - A rectangle is a derived class in reference to a quadrilateral and a base class in reference to a square
- Inheritance examples

Base class	Derived classes
`Student`	`GraduateStudent` `UndergraduateStudent`

`Shape`	`Circle`
	`Triangle`
	`Rectangle`

`Loan`	`CarLoan`
	`HomeImprovementLoan`
	`MortgageLoan`

`Employee`	`FacultyMember` `StaffMember`
`Account`	`CheckingAccount` `SavingsAccount`

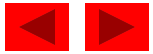


9.2 Inheritance: Base and Derived Classes

- Implementation of **`public`** inheritance

```
class CommissionWorker : public Employee {
   ...
};
```

  - Class **`CommissionWorker`** inherits from class **`Employee`**
  - **`friend`** functions not inherited
  - **`private`** members of base class not accessible from derived class



9.3 `protected` Members

- **`protected`** access
  - Intermediate level of protection between **`public`** and **`private`** inheritance
  - Derived-class members can refer to **`public`** and **`protected`** members of the base class simply by using the member names
  - Note that **`protected`** data “breaks” encapsulation

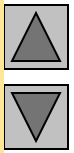
9.4 Casting Base-Class Pointers to Derived Class Pointers

- Derived classes relationships to base classes
  - Objects of a derived class can be treated as objects of the base class
    - Reverse not true — base class objects cannot be derived-class objects
- Downcasting a pointer
  - Use an explicit cast to convert a base-class pointer to a derived-class pointer
  - If pointer is going to be dereferenced, the type of the pointer must match the type of object to which the pointer points
  - Format:

```
derivedPtr = static_cast< DerivedClass * > basePtr;
```


9.4 Casting Base-Class Pointers to Derived-Class Pointers

- The following example:
  - Demonstrates the casting of base class pointers to derived class pointers
  - Class **`Circle`** is derived from class **`Point`**
  - A pointer of type **`Point`** is used to reference a **`Circle`** object, and a pointer to type **`Circle`** is used to reference a **`Point`** object



Outline

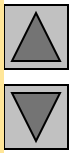
1. Point class definition

----

1. Load header

1.1 Function definitions

```
1  // Fig. 9.4: point.h
2  // Definition of class Point
3  #ifndef POINT_H
4  #define POINT_H
5
6  #include <iostream>
7
8  using std::ostream;
9
10 class Point {
11    friend ostream &operator<<( ostream &, const Point & );
12 public:
13    Point( int = 0, int = 0 );      // default constructor
14    void setPoint( int, int );      // set coordinates
15    int getX() const { return x; }  // get x coordinate
16    int getY() const { return y; }  // get y coordinate
17 protected:         // accessible by derived classes
18    int x, y;       // x and y coordinates of the Point
19 };
20
21 #endif
22 // Fig. 9.4: point.cpp
23 // Member functions for class Point
24 #include <iostream>
25 #include "point.h"
26
27 // Constructor for class Point
28 Point::Point( int a, int b ) { setPoint( a, b ); }
29
30 // Set x and y coordinates of Point
31 void Point::setPoint( int a, int b )
32 {
33    x = a;
```



Outline

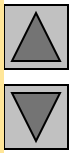
1.1 Function definitions

---

1. `Circle` class definition

```
34    y = b;
35 }
36
37 // Output Point (with overloaded stream insertion operator)
38 ostream &operator<<( ostream &output, const Point &p )
39 {
40    output << '[' << p.x << ", " << p.y << ']';
41
42    return output;   // enables cascaded calls
43 }
44 // Fig. 9.4: circle.h
45 // Definition of class Circle
46 #ifndef CIRCLE_H
47 #define CIRCLE_H
48
49 #include <iostream>
50
51 using std::ostream;
52
53 #include <iomanip>
54
55 using std::ios;
56 using std::setiosflags;
57 using std::setprecision;
58
59 #include "point.h"
60
61 class Circle : public Point {  // Circle inherits from Point
62    friend ostream &operator<<( ostream &, const Circle & );
63 public:
64    // default constructor
```

Class **`Circle`** publicly inherits from class **`Point`**, so it will have class **`Point`**'s **`public`** and **`protected`** member functions and data.



Outline

1. Circle definition

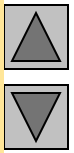
---

1. Load header

1.1 Function Definitions

```
65    Circle( double r = 0.0, int x = 0, int y = 0 );
66
67    void setRadius( double );   // set radius
68    double getRadius() const;   // return radius
69    double area() const;        // calculate area
70 protected:
71    double radius;
72 };
73
74 #endif
75 // Fig. 9.4: circle.cpp
76 // Member function definitions for class Circle
77 #include "circle.h"
78
79 // Constructor for Circle calls constructor for Point
80 // with a member initializer then initializes radius.
81 Circle::Circle( double r, int a, int b )
82    : Point( a, b )       // call base-class constructor
83 { setRadius( r ); }
84
85 // Set radius of Circle
86 void Circle::setRadius( double r )
87    { radius = ( r >= 0 ? r : 0 ); }
88
```

`Circle` inherits from **`Point`**, and has **`Point`**'s data members (which are set by calling **`Point`**'s constructor).



Outline

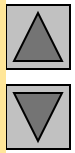
1. 1 Function Definitions

Driver

1. Load headers

1.1 Initialize objects

```
89 // Get radius of Circle
90 double Circle::getRadius() const { return radius; }
91
92 // Calculate area of Circle
93 double Circle::area() const
94    { return 3.14159 * radius * radius; }
95
96 // Output a Circle in the form:
97 // Center = [x, y]; Radius = #.##
98 ostream &operator<<( ostream &output, const Circle &c )
99 {
100   output << "Center = " << static_cast< Point >( c )
101          << "; Radius = "
102          << setiosflags( ios::fixed | ios::showpoint )
103          << setprecision( 2 ) << c.radius;
104
105   return output;   // enables cascaded calls
106}
107// Fig. 9.4: fig09_04.cpp
108// Casting base-class pointers to derived-class pointers
109#include <iostream>
110
111using std::cout;
112using std::endl;
113
114#include <iomanip>
115
116#include "point.h"
117#include "circle.h"
118
119int main()
120{
121   Point *pointPtr = 0, p( 30, 50 );
```



Outline

```
122   Circle *circlePtr = 0, c( 2.7, 120, 89 );
123
124   cout << "Point p: " << p << "\nCircle c: " << c << '\n';
125
126   // Treat a Circle as a Point
127   pointPtr = &c;   // assign address of Circle to pointPtr
128   cout << "\nCircle c (via *pointPtr): "
129        << *pointPtr << '\n';
130
131                                    ith some casting)
132                                    rived-class pointer
133                                    * >( pointPtr );
134                                    Ptr):\n" << *circlePtr
135                                    Ptr
136                                    ;
137
138   // DANGEROUS: Treat a Point as a Circle
139   pointPtr = &p;   // assign address of Point to pointPtr
140
141   // cast base-class pointer to derived-class pointer
142   circlePtr = static_cast< Circle * >( pointPtr );
143   cout << "\nPoint p (via *circlePtr):\n" << *circlePtr
144        << "\nArea of object circlePtr points to: "
145        << circlePtr->area() << endl;
146   return 0;
147}
```

```
Point p: [30, 50]
Circle c: Center = [120, 89]; Radius = 2.70
```

objects

1.2 Assign objects

```
Circle c (via *pointPtr): [120, 89]
```

2. Function calls

Assign **pointPtr** to a **Point** object. It has no derived-class information.

When it is cast to a **Circle ***, **circlePtr** is really assigned to a base-class object with no derived-class information. This is dangerous.

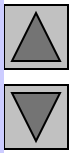
```
Circle c (via *circlePtr):
Center = [120, 89]; Radius = 2.70
Area of c (via circlePtr): 22.90
```

Assign derived-class

"sees" the base-class part of the object it points to.

Cast **pointPtr** into a **Circle ***, and assign to **circlePtr.**

```
Point p (via *circlePtr):
Center = [30, 50]; Radius = 0.00
Area of object circlePtr points to: 0.00
```



Outline

Program Output

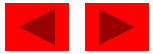
```
Point p: [30, 50]
Circle c: Center = [120, 89]; Radius = 2.70

Circle c (via *pointPtr): [120, 89]

Circle c (via *circlePtr):
Center = [120, 89]; Radius = 2.70
Area of c (via circlePtr): 22.90

Point p (via *circlePtr):
Center = [30, 50]; Radius = 0.00
Area of object circlePtr points to: 0.00
```

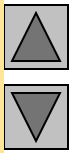
9.5 Using Member Functions

- Derived class member functions
  - Cannot directly access **`private`** members of their base class
    - Maintains encapsulation

9.6 Overriding Base-Class Members in a Derived Class

- To override a base-class member function
  - In the derived class, supply a new version of that function with the same signature
    - same function name, different definition
  - When the function is then mentioned by name in the derived class, the derived version is automatically called
  - The scope-resolution operator may be used to access the base class version from the derived class





Outline

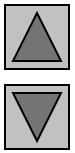
1. Employee class definition

---

1. Load header

1.1 Function definitions

```
1  // Fig. 9.5: employ.h
2  // Definition of class Employee
3  #ifndef EMPLOY_H
4  #define EMPLOY_H
5
6  class Employee {
7  public:
8     Employee( const char *, const char * );  // constructor
9     void print() const;  // output first and last name
10    ~Employee();         // destructor
11 private:
12    char *firstName;     // dynamically allocated string
13    char *lastName;      // dynamically allocated string
14 };
15
16 #endif
17 // Fig. 9.5: employ.cpp
18 // Member function definitions for class Employee
19 #include <iostream>
20
21 using std::cout;
22
23 #include <cstring>
24 #include <cassert>
25 #include "employ.h"
26
27 // Constructor dynamically allocates space for the
28 // first and last name and uses strcpy to copy
29 // the first and last names into the object.
30 Employee::Employee( const char *first, const char *last )
31 {
32    firstName = new char[ strlen( first ) + 1 ];
```



Outline

1.1 Function definitions

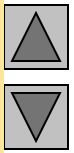
---

1. HourlyWorker class definition

```
33    assert( firstName != 0 ); // terminate if not allocated
34    strcpy( firstName, first );
35
36    lastName = new char[ strlen( last ) + 1 ];
37    assert( lastName != 0 );  // terminate if not allocated
38    strcpy( lastName, last );
39 }
40
41 // Output employee name
42 void Employee::print() const
43    { cout << firstName << ' ' << lastName; }
44
45 // Destructor deallocates dynamically allocated memory
46 Employee::~Employee()
47 {
48    delete [] firstName;   // reclaim dynamic memory
49    delete [] lastName;    // reclaim dynamic memory
50 }
51 // Fig. 9.5: hourly.h
52 // Definition of class HourlyWorker
53 #ifndef HOURLY_H
54 #define HOURLY_H
55
56 #include "employ.h"
57
58 class HourlyWorker : public Employee {
59 public:
60    HourlyWorker( const char*, const char*, double, double );
61    double getPay() const;  // calculate and return salary
62    void print() const;     // overridden base-class print
63 private:
```

HourlyWorker inherits from **Employee**.

HourlyWorker will override the **print** function.

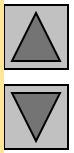


Outline

1. Load header

1.1 Function definitions

```
64    double wage;             // wage per hour
65    double hours;            // hours worked for week
66 };
67
68 #endif
69 // Fig. 9.5: hourly.cpp
70 // Member function definitions for class HourlyWorker
71 #include <iostream>
72
73 using std::cout;
74 using std::endl;
75
76 #include <iomanip>
77
78 using std::ios;
79 using std::setiosflags;
80 using std::setprecision;
81
82 #include "hourly.h"
83
84 // Constructor for class HourlyWorker
85 HourlyWorker::HourlyWorker( const char *first,
86                             const char *last,
87                             double initHours, double initWage )
88    : Employee( first, last )   // call base-class constructor
89 {
90    hours = initHours;  // should validate
91    wage = initWage;    // should validate
92 }
93
94 // Get the HourlyWorker's pay
95 double HourlyWorker::getPay() const { return wage * hours; }
```



Outline

1.1 Function Definitions

---

1. Load header

```
96
97 // Print the HourlyWorker's name and pay
98 void HourlyWorker::print() const
99 {
100    cout << "HourlyWorker::print() is executing\n\n";
101    Employee::print();   // call base-class print function
102
103    cout << " is an hourly worker with pay of $"
104         << setiosflags( ios::fixed | ios::showpoint )
105         << setprecision( 2 ) << getPay() << endl;
106}
107// Fig. 9.5: fig09_05.cpp
108// Overriding a base-class member function in a
109// derived class.
110#include "hourly.h"
111
112int main()
113{
114    HourlyWorker h( "Bob", "Smith", 40.0, 10.00 );
115    h.print();
116    return 0;
117}
```

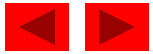
The **`print`** function is overriden in **`HourlyWorker`**. However, the new function still can call the original **`print`** function using **`::`**

```
HourlyWorker::print() is executing

Bob Smith is an hourly worker with pay of $400.00
```

Program Output

9.7 public, private, and protected Inheritance

Base class member access specifier	Type of inheritance		
	`public` inheritance	**`protected`** inheritance	**`private`** inheritance
`Public`	**`public`** in derived class. Can be accessed directly by any non-**`static`** member functions, **`friend`** functions and non-member functions.	**`protected`** in derived class. Can be accessed directly by all non-**`static`** member functions and **`friend`** functions.	**`private`** in derived class. Can be accessed directly by all non-**`static`** member functions and **`friend`** functions.
`Protected`	**`protected`** in derived class. Can be accessed directly by all non-**`static`** member functions and **`friend`** functions.	**`protected`** in derived class. Can be accessed directly by all non-**`static`** member functions and **`friend`** functions.	**`private`** in derived class. Can be accessed directly by all non-**`static`** member functions and **`friend`** functions.
`Private`	Hidden in derived class. Can be accessed by non-**`static`** member functions and **`friend`** functions through **`public`** or **`protected`** member functions of the base class.	Hidden in derived class. Can be accessed by non-**`static`** member functions and **`friend`** functions through **`public`** or **`protected`** member functions of the base class.	Hidden in derived class. Can be accessed by non-**`static`** member functions and **`friend`** functions through **`public`** or **`protected`** member functions of the base class.



9.8 Direct and Indirect Base Classes

- Direct base class
  - Explicitly listed derived class's header with the colon (`:`) notation when that derived class is declared

```
class HourlyWorker : public Employee
```

    - **`Employee`** is a direct base class of **`HourlyWorker`**
- Indirect base class
  - Not listed in derived class's header
  - Inherited from two or more levels up the class hierarchy

```
class MinuteWorker : public HourlyWorker
```

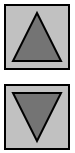
    - **`Employee`** is an indirect base class of **`MinuteWorker`**

9.9 Using Constructors and Destructors in Derived Classes

- Base class initializer
  - Uses member-initializer syntax
  - Can be provided in the derived class constructor to call the base-class constructor explicitly
    - Otherwise base class's default constructor called implicitly
  - Base-class constructors and base-class assignment operators are not inherited by derived classes
    - Derived-class constructors and assignment operators, however, can call base-class constructors and assignment operators

9.9 Using Constructors and Destructors in Derived Classes

- A derived-class constructor
  - Calls the constructor for its base class first to initialize its base-class members
  - If the derived-class constructor is omitted, its default constructor calls the base-class' default constructor
- Destructors are called in the reverse order of constructor calls
  - So a derived-class destructor is called before its base-class destructor



Outline

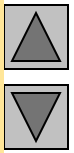
1. `Point` definition

---

1. Load header

1.1 Function definitions

```
1  // Fig. 9.7: point2.h
2  // Definition of class Point
3  #ifndef POINT2_H
4  #define POINT2_H
5
6  class Point {
7  public:
8     Point( int = 0, int = 0 );  // default constructor
9     ~Point();    // destructor
10 protected:      // accessible by derived classes
11    int x, y;    // x and y coordinates of Point
12 };
13
14 #endif
15 // Fig. 9.7: point2.cpp
16 // Member function definitions for class Point
17 #include <iostream>
18
19 using std::cout;
20 using std::endl;
21
22 #include "point2.h"
23
24 // Constructor for class Point
25 Point::Point( int a, int b )
26 {
27    x = a;
28    y = b;
29
30    cout << "Point  constructor: "
31         << '[' << x << ", " << y << ']' << endl;
32 }
```



Outline

1.1 Function definitions

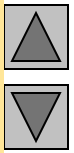
---

1. Load header

1.1 `Circle` Definition

```
33
34 // Destructor for class Point
35 Point::~Point()
36 {
37    cout << "Point  destructor:  "
38         << '[' << x << ", " << y << ']' << endl;
39 }
40 // Fig. 9.7: circle2.h
41 // Definition of class Circle
42 #ifndef CIRCLE2_H
43 #define CIRCLE2_H
44
45 #include "point2.h"
46
47 class Circle : public Point {
48 public:
49    // default constructor
50    Circle( double r = 0.0, int x = 0, int y = 0 );
51
52    ~Circle();
53 private:
54    double radius;
55 };
56
57 #endif
```

`Circle` inherits from **`Point`**.



Outline

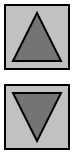
1. Load header

1.1 Function Definitions

```
58 // Fig. 9.7: circle2.cpp
59 // Member function definitions for class Circle
60 #include <iostream>
61
62 using std::cout;
63 using std::endl;
64
65 #include "circle2.h"
66
67 // Constructor for Circle calls constructor for Point
68 Circle::Circle( double r, int a, int b )
69    : Point( a, b )  // call base-class constructor
70 {
71    radius = r;  // should validate
72    cout << "Circle constructor: radius is "
73         << radius << " [" << x << ", " << y << ']' << endl;
74 }
75
76 // Destructor for class Circle
77 Circle::~Circle()
78 {
79    cout << "Circle destructor:  radius is "
80         << radius << " [" << x << ", " << y << ']' << endl;
81 }
```

Constructor for **`Circle`** calls constructor for **`Point`**, first. Uses member-initializer syntax.

Destructor for **`Circle`** calls destructor for **`Point`**, last.



Outline

1. Load headers

1.1 Initialize objects

2. Objects enter and leave scope

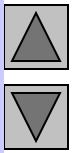
```
82 // Fig. 9.7: fig09_07.cpp
83 // Demonstrate when base-class and derived-class
84 // constructors and destructors are called.
85 #include <iostream>
86
87 using std::cout;
88 using std::endl;
89
90 #include "point2.h"
91 #include "circle2.h"
92
93 int main()
94 {
95    // Show constructor and destructor ca
96    {
97       Point p( 11, 22 );
98    }
99
100   cout << endl;
101   Circle circle1( 4.5, 72, 29 );
102   cout << endl;
103   Circle circle2( 10, 5, 5 );
104   cout << endl;
105   return 0;
106}
```

Object created inside a block destroyed once it leaves scope.

```
Point  constr
Point  destru
```

Remember that the **Point** constructor is called for **Circle** objects before the **Circle** constructor (inside

```
Point  constructor: [72, 29]
Circle constructor: radius is 4.5 [72, 29]

Poin
Circle destructor:  radius is 10 [5, 5]
Point  destructor:  [5, 5]
Circle destructor:  radius is 4.5 [72, 29]
Point  destructor:  [72, 29]
```



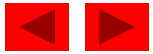
Outline

Program Output

```
Point  constructor: [11, 22]
Point  destructor:  [11, 22]

Point  constructor: [72, 29]
Circle constructor: radius is 4.5 [72, 29]

Point  constructor: [5, 5]
Circle constructor: radius is 10 [5, 5]

Circle destructor:  radius is 10 [5, 5]
Point  destructor:  [5, 5]
Circle destructor:  radius is 4.5 [72, 29]
Point  destructor:  [72, 29]
```

9.10 Implicit Derived-Class Object to Base-Class Object Conversion

- Assignment of derived and base classes
  - Derived-class object can be treated as a base-class object
    - Derived class has members corresponding to all of the base class's members
    - Derived-class has more members than the base-class object
    - Base-class can be assigned a derived-class
  - Base-class object cannot be treated as a derived-class object
    - Would leave additional derived class members undefined
    - Derived-class cannot be assigned a base-class
    - Assignment operator can be overloaded to allow such an assignment



9.10 Implicit Derived-Class Object to Base-Class Object Conversion

- Mixing base and derived class pointers and objects
  - Referring to a base-class object with a base-class pointer
    - Allowed
  - Referring to a derived-class object with a derived-class pointer
    - Allowed
  - Referring to a derived-class object with a base-class pointer
    - Possible syntax error
    - Code can only refer to base-class members, or syntax error
  - Referring to a base-class object with a derived-class pointer
    - Syntax error
    - The derived-class pointer must first be cast to a base-class pointer

9.11 Software Engineering With Inheritance

- Classes are often closely related
  - "Factor out" common attributes and behaviors and place these in a base class
  - Use inheritance to form derived classes
- Modifications to a base class
  - Derived classes do not change as long as the **`public`** and **`protected`** interfaces are the same
  - Derived classes may need to be recompiled

9.12 Composition vs. Inheritance

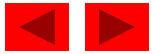
- "Is a" relationships
  - Inheritance
    - Relationship in which a class is derived from another class
- "Has a" relationships
  - Composition
    - Relationship in which a class contains other classes as members

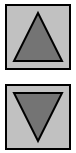
9.13 “Uses A” And “Knows A” Relationships

- “Uses a”
  - One object issues a function call to a member function of another object
- “Knows a”
  - One object is aware of another
    - Contains a pointer or handle to another object
  - Also called an association

9.14 Case Study: Point, Circle, Cylinder

- Point, circle, cylinder hierarchy
  - **`Point`** class is base class
  - **`Circle`** class is derived from **`Point`** class
  - **`Cylinder`** class is derived from **`Circle`** class





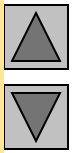
Outline

1. `Point` definition

1.1 Function definitions

```
1  // Fig. 9.8: point2.h
2  // Definition of class Point
3  #ifndef POINT2_H
4  #define POINT2_H
5
6  #include <iostream>
7
8  using std::ostream;
9
10 class Point {
11    friend ostream &operator<<( ostream &, const Point & );
12 public:
13    Point( int = 0, int = 0 );      // default constructor
14    void setPoint( int, int );      // set coordinates
15    int getX() const { return x; }  // get x coordinate
16    int getY() const { return y; }  // get y coordinate
17 protected:         // accessible to derived classes
18    int x, y;       // coordinates of the point
19 };
20
21 #endif
22 // Fig. 9.8: point2.cpp
23 // Member functions for class Point
24 #include "point2.h"
25
26 // Constructor for class Point
27 Point::Point( int a, int b ) { setPoint( a, b ); }
28
29 // Set the x and y coordinates
30 void Point::setPoint( int a, int b )
31 {
32    x = a;
```

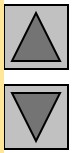
`Point` data members are **`protected`** to be made accessible by **`Circle`**.



Outline

1.1 Function definitions

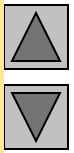
```
33    y = b;
34 }
35
36 // Output the Point
37 ostream &operator<<( ostream &output, const Point &p )
38 {
39    output << '[' << p.x << ", " << p.y << ']';
40
41    return output;          // enables cascading
42 }
```



Outline


```
1  // Fig. 9.9: circle2.h
2  // Definition of class Circle
3  #ifndef CIRCLE2 H
4  #define CIRCLE2_H
5
6  #include <iostream>
7
8  using std::ostream;
9
10 #include "point2.h"
11
12 class Circle : public Point {
13    friend ostream &operator<<( ostream &, const Circle & );
14 public:
15    // default constructor
16    Circle( double r = 0.0, int x = 0, int y = 0 );
17    void setRadius( double );    // set radius
18    double getRadius() const;    // return radius
19    double area() const;         // calculate area
20 protected:          // accessible to derived classes
21    double radius;   // radius of the Circle
22 };
23
24 #endif
25 // Fig. 9.9: circle2.cpp
26 // Member function definitions for class Circle
27 #include <iomanip>
28
29 using std::ios;
30 using std::setiosflags;
31 using std::setprecision;
32
33 #include "circle2.h"
```

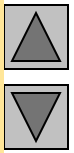
`Circle` data members are **`protected`** to be made accessible by **`Cylinder`**.



Outline

1.1 Function definitions

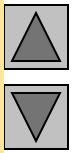
```
34
35 // Constructor for Circle calls constructor for Point
36 // with a member initializer and initializes radius
37 Circle::Circle( double r, int a, int b )
38    : Point( a, b )       // call base-class constructor
39 { setRadius( r ); }
40
41 // Set radius
42 void Circle::setRadius( double r )
43    { radius = ( r >= 0 ? r : 0 ); }
44
45 // Get radius
46 double Circle::getRadius() const { return radius; }
47
48 // Calculate area of Circle
49 double Circle::area() const
50    { return 3.14159 * radius * radius; }
51
52 // Output a circle in the form:
53 // Center = [x, y]; Radius = #.##
54 ostream &operator<<( ostream &output, const Circle &c )
55 {
56    output << "Center = " << static_cast< Point > ( c )
57           << "; Radius = "
58           << setiosflags( ios::fixed | ios::showpoint )
59           << setprecision( 2 ) << c.radius;
60
61    return output;   //  enables cascaded calls
62 }
```



Outline

1. `Cylinder` definition

```
1  // Fig. 9.10: cylindr2.h
2  // Definition of class Cylinder
3  #ifndef CYLINDR2_H
4  #define CYLINDR2_H
5
6  #include <iostream>
7
8  using std::ostream;
9
10 #include "circle2.h"
11
12 class Cylinder : public Circle {
13    friend ostream &operator<<( ostream &, const Cylinder & );
14
15 public:
16    // default constructor
17    Cylinder( double h = 0.0, double r = 0.0,
18              int x = 0, int y = 0 );
19
20    void setHeight( double );   // set height
21    double getHeight() const;   // return height
22    double area() const;        // calculate and return area
23    double volume() const;      // calculate and return volume
24
25 protected:
26    double height;              // height of the Cylinder
27 };
28
29 #endif
```

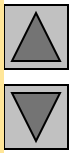


Outline

1.1 Function definitions

```
30 // Fig. 9.10: cylindr2.cpp
31 // Member and friend function definitions
32 // for class Cylinder.
33 #include "cylindr2.h"
34
35 // Cylinder constructor calls Circle constructor
36 Cylinder::Cylinder( double h, double r, int x, int y )
37    : Circle( r, x, y )   // call base-class constructor
38 { setHeight( h ); }
39
40 // Set height of Cylinder
41 void Cylinder::setHeight( double h )
42    { height = ( h >= 0 ? h : 0 ); }
43
44 // Get height of Cylinder
45 double Cylinder::getHeight() const { return height; }
46
47 // Calculate area of Cylinder (i.e., surface area)
48 double Cylinder::area() const
49 {
50    return 2 * Circle::area() +
51           2 * 3.14159 * radius * height;
52 }
53
54 // Calculate volume of Cylinder
55 double Cylinder::volume() const
56    { return Circle::area() * height; }
57
58 // Output Cylinder dimensions
59 ostream &operator<<( ostream &output, const Cylinder &c )
60 {
```

`Circle::area()` is overidden.



Outline

1.1 Function definitions

---

1. Load headers

1.1 Initialize object

2. Function calls

2.1 Change attributes

3. Output data

```
61    output << static_cast< Circle >( c )
62           << "; Height = " << c.height;
63
64    return output;   // enables cascaded calls
65 }
66 // Fig. 9.10: fig09_10.cpp
67 // Driver for class Cylinder
68 #include <iostream>
69
70 using std::cout;
71 using std::endl;
72
73 #include "point2.h"
74 #include "circle2.h"
75 #include "cylindr2.h"
76
77 int main()
78 {
79    // create Cylinder object
80    Cylinder cyl( 5.7, 2.5, 12, 23 );
81
82    // use get functions to display the Cylinder
83    cout << "X coordinate is " << cyl.getX()
84         << "\nY coordinate is " << cyl.getY()
85         << "\nRadius is " << cyl.getRadius()
86         << "\nHeight is " << cyl.getHeight() << "\n\n";
87
88    // use set functions to change the Cylinder's attributes
89    cyl.setHeight( 10 );
90    cyl.setRadius( 4.25 );
91    cyl.setPoint( 2, 2 );
```

```
X coordinate is 12
Y coordinate is 23
Radius is 2.5
Height is 5.7
```

Outline

```
92    cout << "The new location, radius, and height of cyl are:\n"
93         << cyl << '\n';
94
95    cout << "The area of cyl is:\n"
96         << cyl.area() << '\n';
97
98    // display the Cylinder as a Point
99    Point &pRef = cyl;   // pRef "thinks
100   cout << "\nCylinder printed as a Point is: "
101        << pRef << "\n\n";
102
103   // display the Cylinder as a Circle
104   Circle &circleRef = cyl;  // circleRef thin
105   cout << "Cylinder printed as a Circle is:\n
106        << "\nArea: " << circleRef.area()
107
108   return 0;
109}
```

```
The new location, radius, and height of cyl
are:
Center = [2, 2]; Radius = 4.25; Height = 10.00
The area of cyl is:
380.53
```

```
Cylinder printed as a Point is: [2, 2]
```

pref "thinks" **cyl** is a **Point**, so it prints as one.

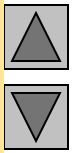
```
Cylinder printed as a Circle is:
Center = [2, 2]; Radius = 4.25
Area: 56.74
```

Circle, so it prints as one.

```
X coordinate is 12
Y coordinate is 23
Radius is 2.5
Height is 5.7

The new location, radius, and height of cyl are:
Center = [2, 2]; Radius = 4.25; Height = 10.00
The area of cyl is:
380.53
Cylinder printed as a Point is: [2, 2]

Cylinder printed as a Circle is:
Center = [2, 2]; Radius = 4.25
Area: 56.74
```

9.15 Multiple Inheritance

- Multiple Inheritance
  - Derived-class inherits from multiple base-classes
  - Encourages software reuse, but can create ambiguities



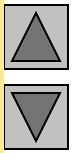
Outline

1. Base1 definition

----

1. Base2 definition

```
1  // Fig. 9.11: base1.h
2  // Definition of class Base1
3  #ifndef BASE1_H
4  #define BASE1_H
5
6  class Base1 {
7  public:
8     Base1( int x ) { value = x; }
9     int getData() const { return value; }
10 protected:      // accessible to derived classes
11    int value;   // inherited by derived class
12 };
13
14 #endif
15 // Fig. 9.11: base2.h
16 // Definition of class Base2
17 #ifndef BASE2_H
18 #define BASE2_H
19
20 class Base2 {
21 public:
22    Base2( char c ) { letter = c; }
23    char getData() const { return letter; }
24 protected:        // accessible to derived classes
25    char letter;   // inherited by derived class
26 };
27
28 #endif
```

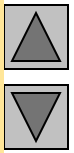


Outline

1. `Derived` Definition

```
29 // Fig. 9.11: derived.h
30 // Definition of class Derived which inherits
31 // multiple base classes (Base1 and Base2).
32 #ifndef DERIVED_H
33 #define DERIVED_H
34
35 #include <iostream>
36
37 using std::ostream;
38
39 #include "base1.h"
40 #include "base2.h"
41
42 // multiple inheritance
43 class Derived : public Base1, public Base2 {
44    friend ostream &operator<<( ostream &, const Derived & );
45
46 public:
47    Derived( int, char, double );
48    double getReal() const;
49
50 private:
51    double real;   // derived class's private data
52 };
53
54 #endif
```

`Derived` inherits from **`Base1`** and **`Base2`**.

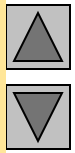


Outline

1. Load header

1.1 Function Definitions

```
55 // Fig. 9.11: derived.cpp
56 // Member function definitions for class Derived
57 #include "derived.h"
58
59 // Constructor for Derived calls constructors for
60 // class Base1 and class Base2.
61 // Use member initializers to call base-class constructors
62 Derived::Derived( int i, char c, double f )
63    : Base1( i ), Base2( c ), real ( f ) { }
64
65 // Return the value of real
66 double Derived::getReal() const { return real; }
67
68 // Display all the data members of Derived
69 ostream &operator<<( ostream &output, const Derived &d )
70 {
71    output << "    Integer: " << d.value
72           << "\n  Character: " << d.letter
73           << "\nReal number: " << d.real;
74
75    return output;   // enables cascaded calls
76 }
77 // Fig. 9.11: fig09_11.cpp
78 // Driver for multiple inheritance example
79 #include <iostream>
80
81 using std::cout;
82 using std::endl;
83
84 #include "base1.h"
85 #include "base2.h"
```



Outline

1. Load header

1.1 Create objects

2. Function calls

```
86 #include "derived.h"
87
88 int main()
89 {
90    Base1 b1( 10 ), *base1Ptr = 0;  // create Base1 object
91    Base2 b2( 'Z' ), *base2Ptr = 0; // create Base2 object
92    Derived d( 7, 'A', 3.5 );       // create Derived object
93
94    // print data members of base class objects
95    cout << "Object b1 contains integer " << b1.getData()
96         << "\nObject b2 contains character " << b2.getData()
97         << "\nObject d contains:\n" << d << "\n\n";
98
99    // print data members of derived class object
100   // scope resolution operator resolves getData amb
101   cout << "Data members of Derived can be"
102        << " accessed individually:"
103        << "\n    Integer: " << d.Base1::getData()
104        << "\n  Character: " << d.Base2::getData()
105        << "\nReal number: " << d.getReal() << "\n\n"
106
107   cout << "Derived can be treated as an "
108        << "object of either base class:\n";
109
110   // treat Derived as a Base1 object
111   base1Ptr = &d;
112   cout << "base1Ptr->getData() yields "
113        << base1Ptr->getData() << '\n';
114
115   // treat Derived as a Base2 object
116   base2Ptr = &d;
```

```
Object b1 contains integer 10
Data members of Derived can be accessed individually:
    Integer: 7
  Character: A
Real number: 3.5
```

Treat **d** as a **Base1** object.

```
Derived can be treated as an object of either base class:
```

Treat **d** as a **Base2** object.

```
base1Ptr->getData() yields 7
```

```
117   cout << "base2Ptr->getData() yields "
118        << base2Ptr->getData() << endl;
119
120   return 0;
121}
```

base2Ptr->getData() yields A

Outline

3. Output data

Program Output

```
Object b1 contains integer 10
Object b2 contains character Z
Object d contains:
    Integer: 7
  Character: A
Real number: 3.5

Data members of Derived can be accessed individually:
    Integer: 7
  Character: A
Real number: 3.5

Derived can be treated as an object of either base class:
base1Ptr->getData() yields 7
base2Ptr->getData() yields A
```