CSC3002-Review-Question-Unofficial-Answer

Ch1: Overview of C++

1. Source file.
2. `//` and `/*  */`.
3. `< >` for C++ Standard library like `<iostream>`, `<vector>`; `" "` for External library defined by users like `“morsecode.h”`.
4. `const double CENTIMETERS_PER_INCH = 2.54;`
5. `main`; `return 0;`.
6. Line break, end current line and output a new line.
7. `int i = 0;` means `int(type) i(name) = 0(value);`. Scope is $-2^{31} \sim 2^{31} - 1$.
8. a, b, c, f, h, k, l

Naming conventions (also a part of programming style)

- The name must start with a letter or the underscore character (_).
- All other characters in the name must be letters, digits, or the underscore. No spaces or other special characters are permitted in names.
- Use meaningful words, but must not be one of the reserved keywords.

9. domain of values & operations
10. domain of values & operations
11. ASCII = *America Standard Code for Information Interchange*
12. true(1), false(0)
13. `double x;`, `cin >> x;`
14. `cout << “i=” << i << “ d = ” << d << “ c = ” << c << “ s = “ << s;`
15. 5 (`int`), 3 (`int`), 3.8 (`double`), 18.0 (`double`), 4 (`int`), 2 (`int`)
16. **Unary minus**: represent negative number, can work as the left value; **Subtraction**: minus two numbers, an operation, requires two numbers to operate.
17. When a number exceeds the scope of its type, the number's bit will be cut down for assignment.

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截断、截断的意思。在C/C++中，将一个超出某类型范围的整数赋给这个类型的变量时，将自动从右端开始截取这个变量能承载的长度赋值。比如，char a=321;，执行后a值是65。因为a的取值范围是-128~127，321(101000001)被从右端起截取了8位(1字节)赋给了a，而01000001刚好是十进制数65。

18. Transform a type to another type. `int i; double j = 9.9; i = int(j);`
19. (a) 4; (b) 2; (c) 42; (d) 42.
20. `a = (x>y) ? x: y;`
21. `++x`: add x by 1 and return; `x++`: return x first and then add x by 1;

22. Only calculate right-side value when necessary. E.g., `if (1 == 1 || x = y)`: this will not judge whether x equals to y since left term is always `true`.

23.
```
if (/*condition*/){ /*expression1*/ } else{ /*expression2*/ };
switch(/*variable*/){
    case 1:{ /*expression1*/ break;}
    case 2:{ /*expression2*/ break;}
    default:{ /*expressionx*/ break;}
}
while(/*condition*/){
    /*expression*/
}
for (/*init*/;/*stop*/;/*step*/){ /*expression*/ }
```

24. Select a case to execute. `break` means exit current switch statement, or the program will execute the consecutive next case.

25. The value to stop iteration.

26.
```
for (int i=1;i<=100;i++) {  }
for (int i=0;i<100;i+=7) {  }
for (int i=100;i>=0; i-=2) {  }
```

Ch2 Functions and Libraries

1. **Function:** receive an input, give an output, part of the program. **Program:** a complete executing unit.
2. **Call:** Invoke the function. **Argument:** variables passed to the function. **Return:** function output value
3. **False.** No need to write a prototype every time, main() also doesn't need.
4. `double sqrt(double i);`
5. Yes. For example, in `if` condition statement.
6. Function that returns a `bool` value.
7. *Overloading*: Define multiple implementation for the same function name (but different function parameters) Use signatures to choose the most appropriate implementation to invoke.

   ## C++ 重载运算符和重载函数

   C++ 允许在同一作用域中的某个**函数**和**运算符**指定多个定义，分别称为**函数重载**和**运算符重载**。

   重载声明是指一个与之前已经在该作用域内声明过的函数或方法具有相同名称的声明，但是它们的参数列表和定义（实现）不相同。

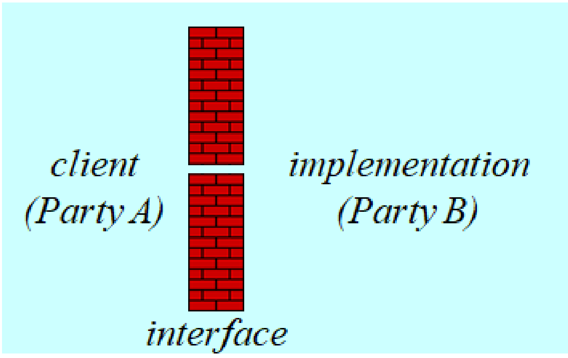
   当您调用一个**重载函数**或**重载运算符**时，编译器通过把您所使用的参数类型与定义中的参数类型进行比较，决定选用最合适的定义。选择最合适的重载函数或重载运算符的过程，称为**重载决策**。

8. Write the variable's initial value in the prototype / function name. E.g., `int f(x, y = 0);`
9. False. `int f(x = 0, y)` is false, it will cause ambiguity when invoking `f(1)`;
10. The memory to store local variables (initialize in function).
11. The value of each argument is copied into the corresponding parameter variable when calling a function.

12. Local is its scope, the variable's life cycle is inside the function. When the function finished, the variable will be destructed.
13. It means *call by reference* [doge], No new variables are created.
14. Use &. E.g., `func(ostream & os)`
15. Explanation from slides:

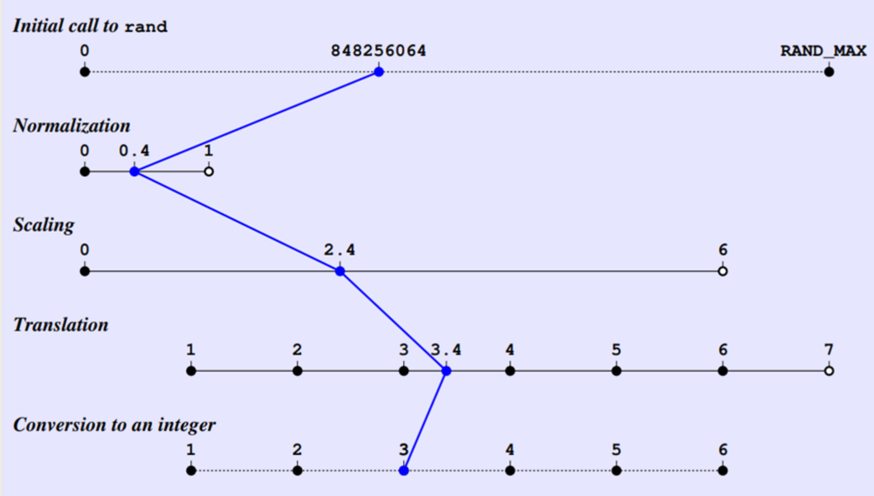
Libraries can be viewed from two perspectives. Code that uses a library is called a ***client***. The code for the library itself is called the ***implementation***.

The point at which the client and the implementation meet is called the ***interface***, which serves as both a barrier and a communication channel:



16. `#include “mylib.h”`
17. Use `extern`
18. Unified, Simple, Sufficient, Flexible, Stable
19. Maintain the same structure and effect. Making changes in the behavior of a library forces clients to change their programs, this reduces its utility.
20. Pseudo random, which means it's not actually pure random, but having some certain rules.
21. Largest `int` type number, $2^{31} - 1$.
22. Explanation from textbook:

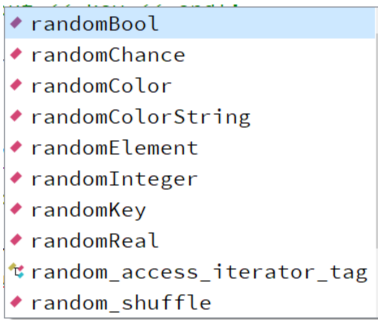
FIGURE 2-13 Steps required to generate a random integer in the range 1 to 6



23. `randomInteger(1, 100)`
24. It depends on the implementation actually. For Stanford Library's case, the answer is Yes, be like $\{-5, -4, -3, \ldots, 3, 4\}$. The source code:

```
int randomInteger(int low, int high) {
    if (!STATIC_VARIABLE(fixedInts).empty()) {
        int top = STATIC_VARIABLE(fixedInts).front();
        STATIC_VARIABLE(fixedInts).pop();
        if (top < low || top > high) {
            // make sure the value is in the given range
            // (assumes that low/high don't overflow int range)
            int range = high - low + 1;
            top = low + std::abs(top) % range;
        }
        return top;
    }
    initRandomSeed();
    double d = rand() / (double(RAND_MAX) + 1);
    double s = d * (double(high) - low + 1);
    return int(floor(low + s));
}
```

25. No, `d1` and `d2` will have the same value.
26. true (if not set the seed according to current time)
27. Initial state of the random number, to generate random sequence.
28. Set the seed fixed.
29. Please see [Stanford Library random.h docs]



Ch3 Strings

1. String is the combination of characters (superset).
2. False (If there is a space, it will only read the part before the space)
3. Both `istream` and `string`.

```
template< class CharT, class Traits, class Allocator >
std::basic_istream<CharT,Traits>& getline( std::basic_istream<CharT,Traits>&& input,
                                           std::basic_string<CharT,Traits,Allocator>& str );
```

4. Method: string.size(). Use a dot after the variable. Function: getline(cin, string); Use a parentheses
5. False. It should be str.length() (method instead of function)
6. s1. Method meaning: replace(pos, len, str) Start from index pos, replace string with length len with sting s2. Please view [docs]
7. Connect two strings.
8. Start from head, compare the ASCII value of each character at the same position until difference. E.g. `“abc” < “abd”` (ASCLL value of ‘d’ is larger than ‘c’)
9. `str[i]`, `str.at(i)`. The latter one will check whether the index is out of boundary.
10. `[]` will not check effectiveness. `.at()` will throw out an exception of “out of range”
11. True
12. True

13. `str.substr(pos, len)`. Start from index `pos`, return a cut string with length `len`. Omit the second parameter: Cut the string until the end. E.g. `“abcde”.substr(2)` is `“cde”`
14. `string::npos`. Please view docs **(?)**
15. repeat with problem (13)
16. It means the finding starts from index `pos`.
17. `5`; `0`; `‘C’`; `“ABCDE”`; `“a”`; `“ZCDE”`; `“ABC”`; `“E”`; `“DE”`; `“DE”`.
18.
```
for (int i=0; i<str.length(); i++){/*do things with str[i]*/}
for (char ch:string) {/*do things with ch*/}
```
19.
```
for (int i=str.length()-1;i>=0;i--) {/*do things with str[i]*/}
```
20. Use `+` operator
21. `False`; `True`; `False`; `7`; `‘A’`; `‘a’`.
22. For the compatibility with C language.
23.
```
// string to char[]:
string str = "abc";
str.c_str();
// char[] to string:
char* cstr = "abc";
str = string(cstr)
```

Ch4 Streams

1. `fstream`, `ifstream`, `ofstream`
2. `<<`: insertion operator `>>`: extraction operator
3. `<<` returns output stream (`cout`). `>>` returns input stream (`cin`). To support chain operations.
4. Operator to change format (`skipws`, `noskipws`, `ws`)
5. Transient: take effect once; Persistent: take effect forever
6. Fixed: fixed-point notation.

   Scientific: scientific notation.

   Default: Round the float number and output.

```
#include <iostream>
#include <iomanip>

using namespace std;

int main() {
    float x = 1231.2254243;
    cout << x << endl;
    cout << fixed << x << endl;
    cout << scientific << x << endl;
    return 0;
}
```

```
C:\Users\ASUS\Desktop\CSC3002\code>.\"notation.exe"
1231.23
1231.225464
1.231225e+03
```

7. Please view the code and materials:

```cpp
#include <iostream>
#include <iomanip>

using namespace std;

const double PI = 3.14159265358979323846;

int main() {
    cout << setprecision(16) << PI << endl;
    cout << setprecision(7) << PI << endl;
    cout << setprecision(15) << scientific << PI << endl;
    cout << setprecision(6) << scientific << uppercase << PI << endl;
    cout << fixed << setprecision(9) << setw(16) << PI << endl;
    cout << fixed << setprecision(4) << setw(8) << setfill('0') << PI << endl;
    return 0;
}
```

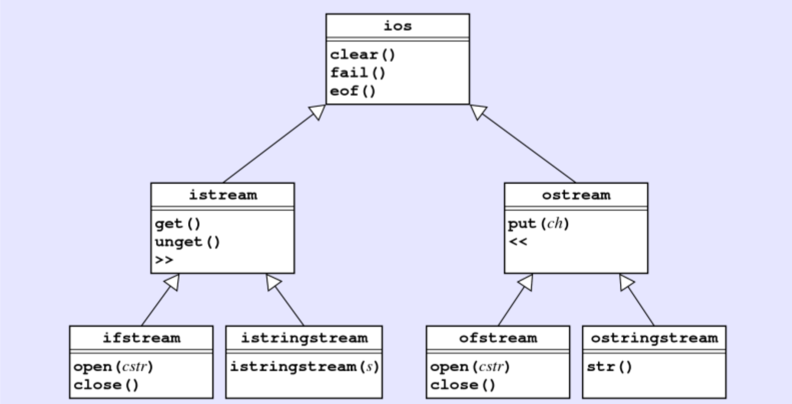
```
3.141592653589793
3.141593
3.141592653589793e+00
3.141593E+00
     3.141592654
003.1416
```

8. For file I/O operations: read file, write file.
9. When using open, one should convert the string to C-style string first. `fstreamName.open(filename.c_str());`
10. Use `fstreamName.fail()`
11. `fstreamName.get() == EOF` or `fstreamName.get() == fstreamName.eof()`
12. There may be other characters like Chinese or Korean outside ASCII range (0~255).
13. Read the character back to the stream. additional materials
14.
```cpp
string stringVar;
while (getline(cin, stringVar)) {/*do things with stringVar*/}
```
Just judge whether the return value of getline() is false;
15. `stringstream` deals with string (commonly used scenario: type conversion). `fstream` deals with file read/write.
16. subclass: subclass; superclass: superclass; inheritance: inheritance.

> 听君一席话，有如听君一席话 (Please check slides)

17. The hierarchy diagram; False, it's a superclass.

FIGURE 4-7 Simplified UML diagram for the stream hierarchy



18. For more general purpose. E.g. deal with `cin` / `cout`, `stringstream`.

19. Can handle error checking. E.g. whether there is a space.
20. Google / Baidu.

Ch5 Collections

1. True. (If you have come to my tutorial, you gonna remember this question, type like `int` / `char` / `double` are defined in representation)
2. Simplicity, Flexibility, Security
3. Standard template library
4. `#include “vector.h”`
5. Dynamic size; Support insert/delete operations; More flexible initialization
6. Check whether the index is out of boundary
7. Classes that include a base-type specification (`vector<int>`)

   The type parameter used in the **`Vector`** class can be any C++ type and may itself be a parameterized type. In particular, you can create a two-dimensional structure by declaring a **`Vector`** whose base type is itself a **`Vector`**. The declaration

   ```
   Vector< Vector<int> > sudoku(9, Vector<int>(9));
   ```

8. `vector<bool>`
9. False. The default size is 0 but not 10
10. `Vector<int> vec(20,0);`
11. The member function: `.size()`
12. 0 to N-1 (The first argument to `insertAt()` is an index number, and the new element is inserted before that position). 0 to N-1 (Remove the element at the index)
13. The operator `[]`
14. To avoid copying a new vector/object and consume great storage and time
15. `Grid<char> chessboard(8,8)`, `vector<vector<char>> chessboard(8, vector<char>(8))`.
16. `chessboard[7][0] = ‘R’;`, `chessboard[7][7] = ‘R’;`.
17. Last In First Out: Stack; First In First Out: Queue;
18. `push()` & `pop()`
19. `enqueue()` & `dequeue()`
20. Return the element at the top (the first one)
21. We can only simulate discrete time instead of continuous time (0, 1, 2, ... minutes)
22. Key & Value.
23. (For example, default value of `int` is 0)

get (*key*)	Returns the value currently associated with *key* in the map. If *key* is not defined, **get** returns the default value for the value type.

24. The operator `[]`
25. Lexicon class is space-efficient and convenient to iterate
26. `.txt` and `.dat` files
27.

```
// C++
for (type var : collection) {};
// Stanford Lib
foreach (type var in collection);
```

28. Destroy the implicit data structure. Destroy their definition and access rules of *FIFO* and *LILO*, can only access element from one side.
29. (Stanford Lib) `Vector`: index order. `Map` & `Set`: no specific order, sometimes alphabetic order

Ch6 Class

1. Find them in PPT
2. public: Accessible and modifiable by instance object. private: Not accessible by external instance but in the internal class definition. The difference is whether it is available to the clients or not.
3. False. Although this is the fundamental difference, but there are other differences like no inheritance for struct and the struct's space is on stack and class on heap.
4. The dot operator `.`
5. `Class name()` (e.g. BigInt())
6. 1, which is the class object itself: *this (just like **self** in python), hidden **(?)**
7. The function to access or set instance variables.
8. Impossible to modify the values of any instance (member) variables.
9. Use the double colon :: (e.g BigInt::) as the namespace
10. Separated files for private part and use `#include` to include them.
11. `int operator% (int x, int y)`
12. prefix (`++date`): first add/minus then return. Suffix (`date++`): first return then add/minus. add an `int` in the parameter list.

```
Date operator++(Date & date);  // prefix
Date operator++(Date & date, int);  // suffix
```

13. Stream type variable cannot copy by value. (If we do not return by reference, it's return by value, the stream will be copied to another variable and return, but it's forbidden)
14. False. It depends.
15. *Method based:* overload operators as a member function, has a default hidden argument: *this, it can access private member variables freely. *Free-function-based:* Easy to read and understand. But no access to private variables unless using "friend" symbol.

```
// method based (in class definition)
Date Date::operator+(int delta) { }
// free function based (outside class definition)
Date operator+(Date date, int delta) { }
```

16. The method or another class can access the private variables of this class.
17. To iterate all directions. To define clockwise/counter-clockwise iteration.
18. Check PPT. (Think – decide private variables – design constructor – design operations/free functions – code, test)
19. A number that can be written as a fraction (a / b).
20. `num` and `den` are relatively prime, `den > 0`
21. No check on divide operator, but on constructor.

```
Rational operator+(Rational r1, Rational r2) {
    return Rational(r1.num * r2.den + r2.num * r1.den, r1.den * r2.den);
}

Rational operator-(Rational r1, Rational r2) {
    return Rational(r1.num * r2.den - r2.num * r1.den, r1.den * r2.den);
}

Rational operator*(Rational r1, Rational r2) {
    return Rational(r1.num * r2.num, r1.den * r2.den);
}

Rational operator/(Rational r1, Rational r2) {
    return Rational(r1.num * r2.den, r1.den * r2.num);
}
```

```
Rational::Rational(int x, int y) {
    if (y == 0) error("Rational: Division by zero");
    if (x == 0) {
        num = 0;
        den = 1;
    } else {
        int g = gcd(abs(x), abs(y));
        num = x / g;
        den = abs(y) / g;
        if (y < 0) num = -num;
    }
}
```

22. `<<` does not need to access private variable, it invokes public function `.toString()`
23. A Logical unit in a string
24. Iterate input, use `scanner.nextToken()` to get next token
25. `TokenScanner scanner();`, `scanner.ignoreWhitespace();`
26. Design method, set public variable/function, private variable/function reasonably.

Ch7 Recursion

1. Invoke the function itself, iterate a certain collection/range. Yes.
2. The function makes use of the same structure of the problem to solve larger problem with smaller parameters and the same interface, invoke itself.
3. n may be smaller than 100. All $n \leq 100$ should belong to the basic case.

```
void collectContributions(int n) {
    if (n <= 100) {
        Collect the money from a single donor.
    } else {
        Find 10 volunteers.
        Get each volunteer to collect n/10 dollars.
        Combine the money raised by the volunteers.
    }
}
```

4. from the textbook:

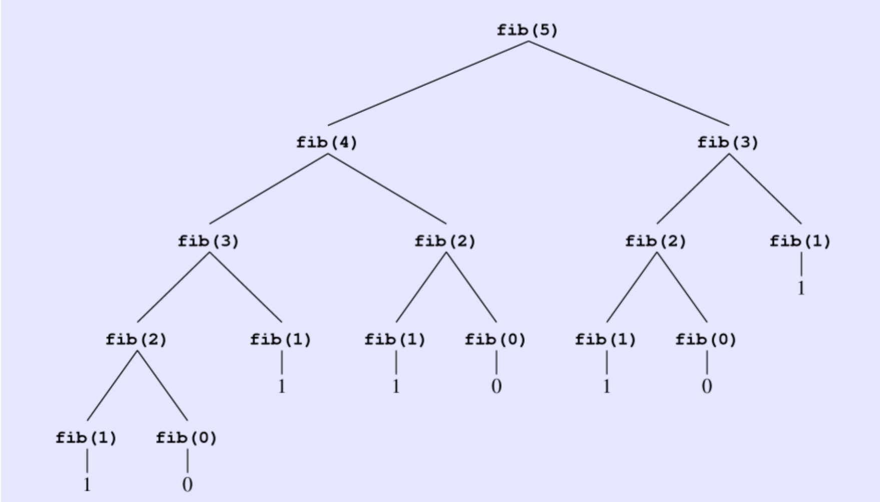
```
if (test for simple case) {
    Compute a simple solution without using recursion.
} else {
    Break the problem down into subproblems of the same form.
    Solve each of the subproblems by calling this function recursively.
    Reassemble the subproblem solutions into a solution for the whole.
}
```

5. from the textbook:

1. You must be able to identify ***simple cases*** for which the answer is easily determined.
2. You must be able to identify a ***recursive decomposition*** that allows you to break any complex instance of the problem into simpler problems of the same form.

6. Divide the problem into a smaller problem and conquer
7. Assuming that any simpler recursive call will work correctly—is called the recursive leap of faith. Whenever you try to understand a recursive program, it is useful to put the underlying details aside and focus instead on a single level of the operation.
8. $fib(3) = fib(2) + fib(1) = 1 + 1 = 2$; Sketch out by yourself
9. Each element of a sequence is defined in terms of earlier elements. $t_n = t_{n-1} + t_{n-2}$
10. $R_n = R_{n-1} + R_{n-2} – R_{n-4}$
11. From the textbook:

FIGURE 7-2 Steps in the calculation of `fib(5)`



12. A wrapper function invoke

```
int fib(int n){
    return additiveSequence(n, 0, 1);
}
```

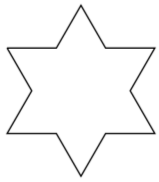
The body consists of a single line of code that does nothing but call another function, passing along a few extra arguments. Functions of this sort, which simply return the result of another function, often after transforming the arguments in some way, are called ***wrapper*** functions. Wrapper functions are extremely common in recursive programming. In most cases, a wrapper function is used—as it is here—to supply additional arguments to a subsidiary function that solves a more general problem.

13. Yes. Calculate one more term.
14. They are the base cases. No. When len = 1, the invoke term len-2 could be -1.
15. Check whether the middle term is palindrome after checking the characters on two sides.
16. You call me, I call you.
17. Mutual recursion will happen and never ends. No reduce, No simple case.
18. `isEven(1) = isOdd(0) = isEven(-1) = ….` Basic case is not complete.

Ch8 Recursive Strategies

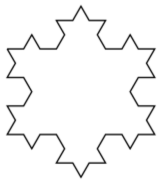
1. `tower(n,A,B,C) = tower(n-1,A,C,B) + 1(A->C) + tower(n-1,B,A,C)` (Move n disks from A to C = Move the up n-1 disks from A to B + Move the lowest disk from A to C + Move the n-1 disks from B to C)
2. The b step will fail since larger disk cannot place upon smaller disk, the temporary spire is unavailable.
3. A->C A->C
4. Permutation, 排列
5. The first insight is to pick any character as the first one in the permutation, and perform full permutations on the remaining. The second is to pick the first character out, perform full permutations on the remaining and insert the character to the n positions in the results. Both generate: $F(n) = n * F(n-1) \rightarrow O(N!)$ $
6. $4! = 24$
7. Set the minimum area, if width * height is smaller than the minimum area, terminate!
8. like:

Applying this transformation to each of the three sides of the original triangle generates the Koch snowflake of order 1, as follows:



9. One-order segment has 12 lines, two-order segments has 12 * 4 = 48 lines.

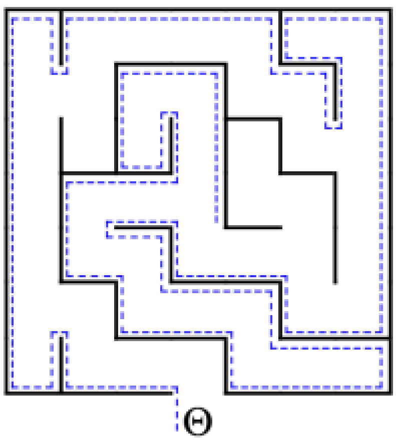
If you then replace each line segment in this figure with a new line that again includes a triangular wedge, you create the following order-2 Koch snowflake:



Ch9 Backtracking Algorithms

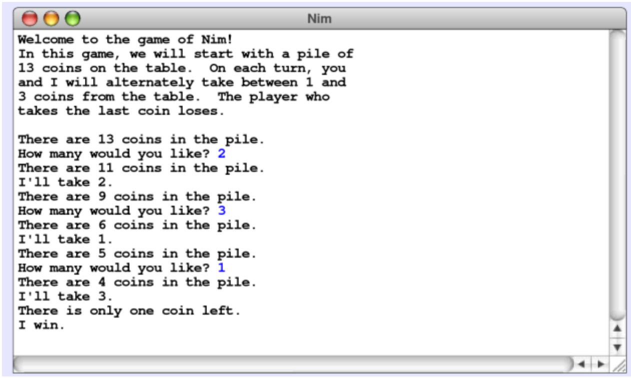
1. Iterative
2. Put your right hand on the wall and follow. Yes.

```
Put your right hand against a wall.
while (you have not yet escaped from the maze) {
    Walk forward keeping your right hand on a wall.
}
```



3. At least one sub-problem has a solution (all choice for the direction)
4. Walk out of maze (To the end) or no available direction to choose.
5. Avoid calculating the sub-problem repetitively. May cause infinite loop
6. If all directions in the for loop ends up with no solution, it should unmark and try other solution in the previous step. A successful solution may go through part of the failed trial path. Yes.
7. Judge whether the sub-problem has a solution and transfer the information to previous/next step. Also, to end the for loop.
8. Try all four directions and move by one step each time to check whether there is a solution starting from the current position.
9. Bad. Whatever you pick (say i), your opponent will pick $(4 - i)$ coins, and finally leaves the last one for human player.

configuration. In this particular version, the game begins with a pile of 13 coins. On each turn, players take either one, two, or three coins from the pile and put them aside. The object of the game is to avoid being forced to take the last coin.



10. If nCoins is (4n + 1) then it's bad, otherwise it's good. (Can pick 1/2/3 each time)
11. Minimize the maximum of your opponents' rating. Consider your opponents, game theory
12. To apply in a more general sense. Have a grasp of the ideology.
13. Pass the information of individual step during the backtracking. Judge whether reaching the end and terminate.
14. The **`evaluateStaticPosition`** method evaluates a particular state in the game without making any further recursive calls.
15. To maximize your minimum score. The second position. -3.

In the following chapters, some questions are not covered in the lecture, so they will be skipped and be denoted with `/`.

Ch10 Algorithmic Analysis

1. Iterative > recursive
2. Make the item in order
3. The first `lh` numbers is already in order, iterating them brings extra cost.

```
/*
 * Function: sort
 * --------------
 * This implementation uses an algorithm called selection sort, which can
 * be described as follows.  With your left hand (lh), point at each element
 * in the vector in turn, starting at index 0.  At each step in the cycle:
 *
 * 1. Find the smallest element in the range between your left hand and the
 *    end of the vector, and point at that element with your right hand (rh).
 *
 * 2. Move that element into its correct position by exchanging the elements
 *    indicated by your left and right hands.
 */

void sort(Vector<int> & vec) {
   int n = vec.size();
   for (int lh = 0; lh < n; lh++) {
      int rh = lh;
      for (int i = lh + 1; i < n; i++) {
         if (vec[i] < vec[rh]) rh = i;
      }
      int tmp = vec[lh];
      vec[lh] = vec[rh];
      vec[rh] = tmp;
   }
}
```

4. Selection sort is $O(N^2)$, $50 * (1000/250)^2 = 800ms$
5. $(N+1) * N/2$
6. /
7. True.
8. /
9. Yes. It is just the same as $O(N^2)$

To show that this expression is indeed true under the formal definition of big-O, all you need to do is find constants C and N_0 so that

$$\frac{N^2+N}{2} \leq C \times N^2$$

10. Yes. Selection sort $f(n) = O(N^2) <= O(N^3)$ Only if it's "smaller or equal than".
11. No. $O(N \log N) < O(N^2)$
12. $O(N^2)$
13. $O(1)$ (constant)
14. /
15. from the textbook:

$$t(N) = O(f(N))$$

The formal meaning of this expression is that $f(N)$ is an approximation of $t(N)$ with the following characteristic: it must be possible to find a constant N_0 and a positive constant C so that for every value of $N \geq N_0$, the following condition holds:

$$t(N) \leq C \times f(N)$$

In other words, as long as N is "large enough," the function $t(N)$ is always bounded by a constant multiple of the function $f(N)$.

16. Merge compare the two arrays one by one and pick the smaller one out each time. All the numbers are iterated exactly once.
17. It doesn't matter. The two lines just put the remaining numbers (the largest ones) at the end of the ordered array. Only one array has remains so pick any of the two is ok.
18. /
19. Can be expressed as a power of N.
20. Whether the complexity is exponential.
21. From the textbook:

```
/*
 * Function: partition
 * -------------------
 * This function rearranges the elements of the vector so that the
 * small elements are grouped at the left end of the vector and the
 * large elements are grouped at the right end.  The distinction
 * between small and large is made by comparing each element to the
 * pivot value, which is initially taken from vec[start].  When the
 * partitioning is done, the function returns a boundary index such
 * that vec[i] < pivot for all i < boundary, vec[i] == pivot
 * for i == boundary, and vec[i] >= pivot for all i > boundary.
 */
```

```
int partition(Vector<int> & vec, int start, int finish) {
   int pivot = vec[start];
   int lh = start + 1;
   int rh = finish;
   while (true) {
      while (lh < rh && vec[rh] >= pivot) rh--;
      while (lh < rh && vec[lh] < pivot) lh++;
      if (lh == rh) break;
      int tmp = vec[lh];
      vec[lh] = vec[rh];
      vec[rh] = tmp;
   }
   if (vec[lh] >= pivot) return start;
   vec[start] = vec[lh];
   vec[lh] = pivot;
   return lh;
}
```

22. $O(N^2)$ (consider a completely ordered reversed array, each time you iterate the whole array but can only identify one position but not make a good partition) $O(N\log N)$
23. Base case $\longrightarrow$ Iterative step
24. /

Ch11 Pointers and Arrays

1. Bit: The smallest memory unit, a single binary bit {0, 1}

Byte: The smallest transferable/addressable unit

Word: The biggest bytes a CPU can process each time. Depend on the system, might be 4bytes or 8 bytes

2. Binary digit
3. $2*1024*1024*1024$ bytes.
4. (a)0x11; (b)0x100; (c) 0x6C1; (d) 0xACE.
5. (a) 23; (b) 100; (c) 204; (d) 4013.
6. `char`: 1; `double`: 8.
7. T
8. T
9. 11111111111111111111111111111001 (take inverse at every bit and then plus 1)
10. Stack frame + Heap + Static Data Region
11. Get actual number of bytes required to store a value of type t / variable x. `sizeof()` [docs]

```
1) sizeof empty class:           1
2) sizeof pointer:               8
6) sizeof(Bit) class:            4
7) sizeof(int[10]) array of 10 int: 40
8) sizeof a        array of 10 int: 40
9) length of array of 10 int:    10
A) length of array of 10 int (2): 10
B) sizeof the Derived class:     8
C) sizeof the Derived through Base: 4
D) sizeof(unsigned)              4
E) sizeof(int)                   4
F) sizeof(short)                 2
G) sizeof(char)                  1
H) sizeof(CharChar)              2
I) sizeof(CharCharInt)           8
J) sizeof(IntCharChar)           8
K) sizeof(CharIntChar)           12
L) sizeof(CharShortChar)         6
```

12. /
13. Left value, can place at the left hand side in the value assignment. A left value can store data and corresponds to an address in memory
14. A compact way to refer to large data structure; Convenient to dynamically allocate memory. Record the relationships of data items (linked list)
15. `p1`: Integer Pointer. `p2`: Integer.
16. `*`: dereferencing. `&`: referencing, obtain address
17. Pointer assignment: Assign an address of an item to the pointer, the pointer will store the address of that item and point to the new item now.

    Value assignment: Assign the value to an item, its address in the memory is still the same.
18. Skipped. Just remember that in stack frame the address grows from high value to low value
19. T
20. F (`*` dereferencing is not always meaningful, when `p` is an `int`, it fails)
21. Pass the pointer as the argument
22.
```
float realArray[100];
bool inUse[16];
string lines[1000];
```
23.
```
int squares[11];
for (int i=0; i<11; i++)
    squares[i] = i * i;
```
24. Allocated size: the allocated size of the array during declaration. Effective size: How many elements in the array are actively in use (initialized)
25. Calculate j+3 --> Find the address of intArray (address of the first element) --> Indexing, Add this address by 4* (j + 3) (bytes, 4 since an integer occupies 4 bytes) --> Access the value intArray[j+3] --> Referencing, return the address of the value
26. `array[2]` is the third element of the array, it will return the value. `array + 2` will return the address of array's address + 2 * size of an element. `&array + 2` will return array's address + 2 * size of the array

```
double a[3] = {1.0, 2.0, 3.0};
cout << a << " " << a + 1 << " " << &a + 1 << endl;
```

```
C:\Users\ASUS\Desktop\CSC3002\code>.\"memory.exe"
0x61fe00 0x61fe08 0x61fe18
```

27. FF28 (FF00 + 5 * 0x8 = FF00 + 0x28 = FF28, pay attention it is hexadecimal here)
28. F. It will add the size of the type p is pointing to (int à 4 bytes)

```
int i = 0;
int* j = &i;
cout << j << endl;
j++;
cout << j << endl;
```

```
0x61fe14
0x61fe18
```

29.
    1. Dereference p, return *p at first, and then increment p by the size of the type it points to.

    ```
    int i = 3002;
    int* j = &i;
    cout << j << endl;
    cout << *j++ << endl;
    cout << j << endl;
    ```

    ```
    0x61fe14
    3002
    0x61fe18
    ```

    2. If it's *++p, then p will increment first and then deference, return (cause an undefined behavior)

    ```
    int i = 3002;
    int* j = &i;
    cout << j << endl;
    cout << *++j << endl;
    cout << j << endl;
    ```

    ```
    0x61fe14
    6422040
    0x61fe18
    ```

30. `++` is applied first. From right to left.

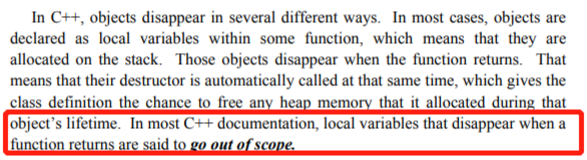
Ch12 Dynamic Memory Management

1. See the photo below:

    Up to this point in the text, you have seen two mechanisms for assigning memory to variables. When you declare a global constant, the compiler allocates memory space that persists throughout the entire program. This style of allocation is called ***static allocation*** because the variables are assigned to locations in memory that remain unchanged throughout the lifetime of the program. When you declare a local variable inside a function, the space for that variable is allocated on the stack. Calling the function assigns memory to the variable; that memory is freed when the function returns. This style of allocation is called ***automatic allocation.*** There is, however, a third way of allocating memory that permits you to acquire new memory as the program runs. The process of acquiring new storage while the program is running is called ***dynamic allocation.***

2. The pool of unallocated memory available to a program is called the heap. For dynamic allocation (new)
3. Maximize available space
4.
    ```
    bool* bp;
    Point* pp(3,4);
    string* name = new string[100];
    ```
5. only for the last one: delete[] name;

6. cell: the basic element unit in the list, contains the data field and the link. link: represent the relationship between the cells
7. Use `NULL` Make the last element point to `NULL`.
8.
```
struct Cell{
    int value;
    Cell* link
}
```
9.
```
Cell* head = new Cell;
for (Cell* cur = head; cur! = NULL; cur = cur->link){ }
```
10. Program fails to free the heap memory allocated.
11. F (No garbage collection in C++ but in Java)
12. Release the memory occupied by the class. Avoid memory leak.
13. `~IntArray();`
14. from the textbook:



In C++, objects disappear in several different ways. In most cases, objects are declared as local variables within some function, which means that they are allocated on the stack. Those objects disappear when the function returns. That means that their destructor is automatically called at that same time, which gives the class definition the chance to free any heap memory that it allocated during that object's lifetime. In most C++ documentation, local variables that disappear when a function returns are said to ***go out of scope.***

15. T (Destructor will automatically be invoked when a local variable / temporary value go out of scope)

16. Initialize a larger array with bigger size when expanding, and copy elements in the original array to the new.
17. Initial capacity; char* array store data; capacity; count – current element number
18. Allocate a new array, copy original array to the new, delete original array
19. No, If the current size reaches capacity, every push method will require O(N) to copy and expand the array, causing the average complexity O(N);
20. Reclaimed: 回收. Whenever your program creates local variables in a function. When the function returns or the block ends (e.g. for {...}), go out of scope.

21. Whenever the program uses new. When the program uses delete.
22. To track what the program is doing and the address – value relationship.
23. Add &， write the original variable address in the square, add an arrow
24. *this (The object / class itself, just like **self** in python)
25. To test a small part of the code. The test program that checks the correctness of that module in isolation from the rest of the code.
26. Shallow copy: Dynamic variables are copied as address not the data, the two items share one heap memory,

    Deep copy: Dynamic variables are copied as data, Copy the heap memory at the same time

    C++ uses **shallow copy** by default
27. Override the **=** operator and the copy constructor
28. The referenced variables/objects cannot be changed. (Will not change the value of that parameter)
29. The data fields of the class will not be changed. Classes that use the const specification for all appropriate parameters and methods.
30. You can use the Proportional Sequence Summation Formula. $\lim_{k \to +\infty} 1 * (1–0.5^k)/(1–0.5) = 2$. Or you can use mathematical induction to explain the sum is (1-1/2^k)

Ch13 Efficiency and Representation

1. F (Time + Space)
2. What you see is what you get
3. Use command line to edit texts
4. I: `.insertCharacter(ch)`; J: `.moveCursorToStart()`; E: `.moveCursorToEnd()`; F: `.moveCursorForward()`; B: `.moveCursorBackward()`; D. `.deleteCharacter()`.
5. From the slides:

`buffer.getText()`	Returns the contents of the buffer as a string.
`buffer.getCursor()`	Returns the position of the cursor.

6. I and D: move the elements of the inserted/deleted element afterwards by one step, causing many element movements.
7. Before (peek à end)：DCBA after：EFGHIJ. Imagine splitting it in the middle.
8. Between the top elements of two (before & after) stacks.
9. J and E
10. Add a possible position for the cursor. If there are n cells, there will be $n+1$ possible positions for the cursor. (Point to Cell A then the cursor will be after Cell A
11. At the beginning. When there is no element, the cursor is at the beginning
12. Create a new cell --> Assign value to the new cell --> Let the new cell link to the next cell of the cursor --> Let the cursor's cell link to the new cell --> Let the cursor point to the new cell

```
void EditorBuffer::insertCharacter(char ch) {
   Cell *cp = new Cell;
   cp->ch = ch;
   cp->link = cursor->link;
   cursor->link = cp;
   cursor = cp;
}
```

13. Start（dummy）—H—E—L—L—O The cursor points to the first L

14. Start（dummy）—H—E—L—X—L—O The cursor points to X

15. Go through the linked list

16.

```
Cell* head = new Cell;
for (Cell* cur = head; cur! = NULL; cur = cur->link){ }
```

17. J and E. The linked list cannot access the previous cell and the last cell directly, must traverse the list.

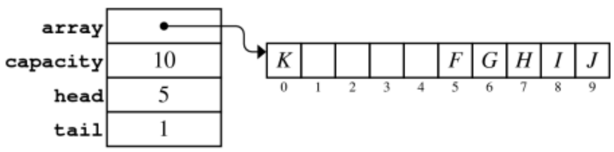
18. Time-space tradeoff is the tradeoff between time and space

19. Double linked list, add a link to the previous cell

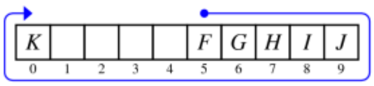
20. Time-space tradeoff, more space consumption. (Buy a new computer maybe)

Ch14 Linear Structures

1. More generality, can accommodate different types. No overloading one by one
2. template `<typename placeholder>`
3. /
4. An integer array. An integer (store the size). Two integers representing the indices of head and tail.
5. A ring structure buffer. Use head and tail to mark the beginning and the end. Applied in Array-based queue



If you allow the elements in the queue to wrap around from the end of the array to the beginning, the active elements always extend from the **head** index up to the position immediately preceding the **tail** index, as illustrated in this diagram:



6. Whether `head==tail`. Compare the current size `(tail - head + capacity) % capacity` with `capacity`.
7. /
8. The technique of using remainders to reduce the result of a computation to a small, cyclical range of integers is an important mathematical technique called modular arithmetic. Let index inside the range 0 ~ capacity - 1
9. Tail may be smaller than head and generate a negative number (like the above image) Should be (tail – head + capacity) % capacity
10. /
11. Whether the head or tail pointer is `NULL`; see the `count` variable.

12. `Typename & Classname::operator[](Typename);`

```
template <typename ValueType>
ValueType & Vector<ValueType>::operator[](int index) {
   if (index < 0 || index >= count) error("Vector index out of range");
   return array[index];
}
```

Ch15 Maps

1. Order the Key. Binary search each time
2. Inserting an element in a vector costs $O(N)$ to move elements right
3. Two-dimension
4. The first character represents `NULL` (special), the program will ignore.
5. Bucket is the element of an array, representing one hashcode's result. That array contains all the key-value pairs with a specific hash code.
6. Different keys generate the same hash code and fall into the same bucket.
7. The default copy constructor will help you copy the local vector (not in heap)

```
/* Make copying illegal */

   StringMap(const StringMap & src) { }
   StringMap & operator=(const StringMap & src) { return *this; }
```

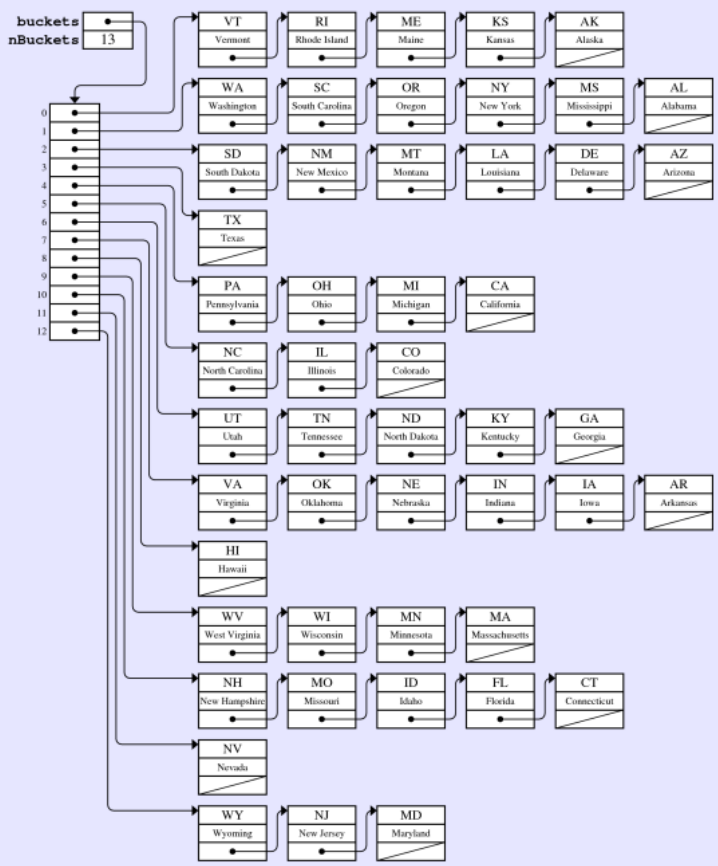
8. Given the index of the bucket and the key, find whether there is the key in the bucket.

```
StringMap::Cell *StringMap::findCell(int bucket, const string & key) const {
   Cell *cp = buckets[bucket];
   while (cp != NULL && key != cp->key) {
      cp = cp->link;
   }
   return cp;
}
```

9. The key has no relationship with the string str. You cannot access the key with the string next time.
10. Yes. But all keys with go to one bucket (need to deal with collision) and complexity becomes O(N)
11. AZ and DE

    The first collision happens when two keys generate a same hash value and put into the same bucket. So we need to find which bucket obtains two elements the first. Following the alphabetic order (check from tail), AK --> AL --> AR --> AZ --> CA --> CO --> CT --> DE (collision with AZ!)

FIGURE 15-9 Hash table containing the state abbreviations



12. Raise bucket number (space), reduce the probability of collision and improve insert & find efficiency (time).
13. Number of keys / number of buckets
14. 0.7

For good performance, you want to make sure that the value of λ remains small. Although the mathematical details are beyond the scope of this text, maintaining a load factor of 0.7 or less means that the average cost of looking up a key in a map is $O(1)$. Smaller load factors imply that there will be lots of empty buckets in the hash

15. Change the number of buckets and push the elements inside the hash table again (with new bucket index maybe)
16. The key type must support the == comparison operator so that the code can tell whether two keys are identical.
17. Use two-dimension look-up table

Ch16 Trees

1. Every node requires a collection to store the child nodes. No loop/circle formed.
2. Family tree, C++ class inheritance...
3. /
4. Root: Henry VII height=5
5. Node*, the pointer
6. /
7. At most two child nodes for each node. Left child node is smaller than right.
8. Since the current node may be modified. (The root node changes)

argument, it must be passed by reference. Instead of taking a **BSTNode *** as its argument the way **findNode** does, **insertNode** must instead take that node pointer by reference. The prototype for **insertNode** therefore looks like this:

```
void insertNode(BSTNode * & t, const string & key);
```

9. /
10. /
11. /
12. Inorder. Processing the current node between the two recursive calls represents an inorder traversal. No matter what order the nodes are inserted into the tree, in-order traversal will always generate the nodes in order (from small to large)
13. The height difference between any node's two child trees is no larger than 1
14. (a) yes; (b) no (For left child of the root node: left height is 2 and right height is 0; For right child of the root node: left 0, right 2) (c) yes.
15. F. They can still work correctly but with complexity $O(N)$
16. Difference between the left child tree and right child tree
17. A=0 E=2 O=1 I=0 Y=1 U=0
18. (Not covered in this course, learn more about it in the course CSC3100 or CSC4120)
19. T
20. /
21. See the photo below:

```
void insertNode(BSTNode * & t, const string & key) {
   if (t == NULL) {
      t = new BSTNode;
      t->key = key;
      t->left = t->right = NULL;
   } else {
      if (key != t->key) {
         if (key < t->key) {
            insertNode(t->left, key);
         } else {
            insertNode(t->right, key);
         }
      }
   }
}
```

22. Use the rightmost node in left child tree or leftmost node in right child tree to replace the removed node
23. 1521-2193-1604-3169-2708-1861. (insert 1521 as the last element and move up twice)
24. The representation is different, a heap is an array structure used to simulate the partially ordered trees (tree structure). But the mechanism is the same.

Ch17 Sets

1. T
2. F
3. Empty set, Integer set, Natural number set, Real number set
4. Belong to / not
5. $\{0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100\}$
6. $\{x|x = 9i, i \in N, 0 \le i \le 9\}$
7. $\cup, \cap, -$

8. $\{a, b, c, e\}$, $\{a, c\}$, $\{b\}$, $\{b\}$.
9. A proper subset does not include the set itself
10. $\{i|i \in N\}$, $\{i^2|i \in N\}$
11. /
12. $(A \cap B) \cup (A \cap C) \cup (B \cap C) - (A \cap B \cap C)$.
    $(A \cap B \cup C - (A \cap C) \cup (B \cap C)) \cup (A \cap B \cap C)$
13. /
14. /
15. Map, each key element is unique and no repetition
16. From the textbook:

    Boolean arrays in which the elements indicate whether the corresponding index is a member of some set are called ***characteristic vectors.*** The following examples illustrate how the characteristic-vector strategy can be used to represent the indicated sets, assuming that **`RANGE_SIZE`** has the value 10:

    $\varnothing$

F	F	F	F	F	F	F	F	F	F
0	1	2	3	4	5	6	7	8	9

    $\{1, 3, 5, 7, 9\}$

F	T	F	T	F	T	F	T	F	T
0	1	2	3	4	5	6	7	8	9

    $\{2, 3, 5, 7\}$

F	F	T	T	F	T	F	T	F	F
0	1	2	3	4	5	6	7	8	9

17. No repeated element, the character must be in ASCII with length smaller than 128
18. F T F F T F F F F T
19. Number 0-9. `isnum(char)`
20. YES
21. (a). 0000000001001001

    (b). 0100100011111111

    (c). 0100100010110110

    (d). 0000000000000000

    (e). 1011011110110110

    (f). 0100100000000000 (only x[i] = 1 y[i] = 0 can have bit 1)

    (g). 1011011100000000 (only x[i] = 0 y[i] = 0 can have bit 1)

    (h). 0000000000001111

    (i). 0100001001001000

    (j). 0000000001001000
22. Octal: 44111 (Check 3 bits together) Hexadecimal: 00FF (Check 4 bits together)
23. (a). `x & mask`; (b). `x |= mask` (c). `x &= ~mask` (d). `x ^= mask`.
24. `unsigned(1) << k`

Ch18 Graphs

1. /

2. T
3. Whether an edge has direction
4. Add two edges between two nodes
5. /
6. Neighbor: How many nodes are one edge around the node

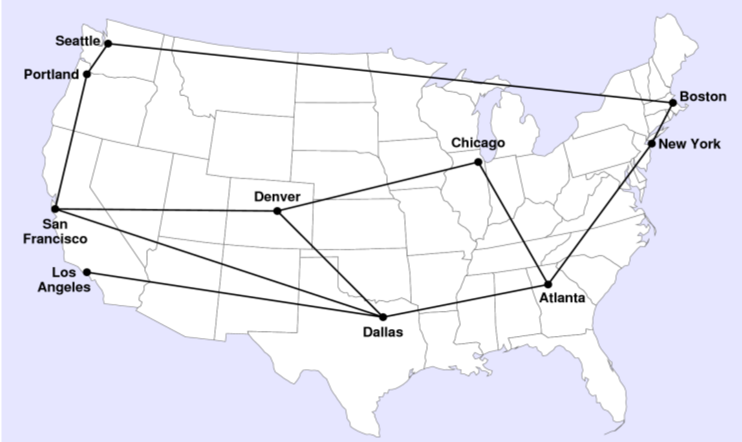
   Degree: How many edges are connected with the node
7. Whether starting from a node can reach any other node
8. T
9. Vertex, Edge
10.
```
V= {CS1, CS2, CS3, CS4, CS5, CS6, CS7, CS8}
E= {CS1 -> CS2, CS2 -> CS3, CS2 -> CS4, CS2 -> CS5, CS3 -> CS7, CS3 -> CS8,
CS4 -> CS6, CS5 -> CS6, CS5 -> CS7, CS5 -> CS8 }
```
11.
```
CS1 -> (CS2)
CS2 -> (CS3, CS4, CS5)
CS3 -> (CS7, CS8)
CS4 -> (CS6)
CS5 -> (CS6, CS7, CS8)
CS6 -> ()
CS7 -> ()
CS8 -> ()
```
12. The matrix looks like:

$$\begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

13. Density (number of edges / number of nodes)
14. Whether the graph is sparse (adjacency list) of dense (adjacency matrices)
15. There are different traversal order
16. To save space. Use a compact way to represent large data structure and easy to reference the neighboring nodes / arcs.
17. DFS & BFS
18. DFS: Atlanta -> Chicago -> Denver -> Dallas -> Los Angeles -> San Francisco -> Portland -> Seattle -> Boston -> New York

    BFS: Atlanta -> Chicago -> Dallas -> New York -> Denver -> Los Angeles -> San Francisco -> Boston -> Portland -> Seattle

FIGURE 18-1 Route map for a small airline serving ten cities



19. Refer to the textbook:

> The critical implication of this observation is that the sets and structures used to represent the graph cannot contain **Node** and **Arc** values directly. The need to share common structures means that all of the internal references to these structures must specify *pointers* to **Node** and **Arc** values. The sets in the **SimpleGraph** structure, therefore, must use **Node *** and **Arc *** as their element type and not the underlying structure types themselves. The same is true for the set of arcs in the **Node** structure and the references to nodes in the **Arc** structure. Figure 18-3 shows the structure of

Also Check 18.5 explanation

> If the primary goal in redesigning the **graph.h** interface is to take maximum advantage of object-oriented design, the obvious strategy is to replace each of the low-level structures with a class. Under this strategy, the interface would export a **Graph** class in the place of the **SimpleGraph** structure, along with classes corresponding to the **Node** and **Arc** types. The private fields in each of those classes would presumably match those in the corresponding structure. Clients, however, would gain access to those fields through method calls instead of through direct references.

20. Node must include a name and set<ArcType *> arcs. ArcType must include a NodeType * start and a NodeType * finish.
21. Choose the most beneficial behavior in the (every) current step but may not be globally the most beneficial.
22. [Material Link] Learn more about it in CSC3100 or CSC4120
23. Check textbook
24. Check textbook

Ch19 Inheritance

1. `class SubClass: public SuperClass{ };`
2. T (It can be non-template and no specification)
3. F (The parameter lists may be different)
4. Allow sub-class to override super-class method. Dynamic banding. When invoking methods, choose the pointer's pointing type instead of pointer's initialization type.
5. A pure virtual method will never be executed in the super-class but in sub-class. To guarantee security. No need to write **virtual** in the sub-class.
6. Add `=0` at the end. E.g., `virtual double getPay() = 0;`.
7. An abstract class cannot be instantiated (but can define its pointer) and can only serve as the parent class of other classes. Yes, can provide implementation or leave the method empty.

8. Assign value of sub-class to super-class. Slicing will throw off all fields in sub-class but not in the super-class.
9. Pointers. There may be slicing if storing values.
10. draw(gw)
11. Protected section is visible/available to sub-class but not to clients. Public section is visible to all. Private section is only visible to the class itself.
12. A different version of the superclass constructor. Use sub-class's constructor to initialize super-class. Appear in sub-class's constructor

    In some cases, however, it may be useful to call some other variant of the constructor besides the parameterless default version. C++ allows you to do so by including an additional specification in the code for the subclass constructor called an ***initializer list.*** The initializer list appears just before the brace that begins the

    FIGURE 19-7 Implementation of the `Circle` class showing the use of an initializer list

```
/*
 * Implementation notes: Circle
 * ----------------------------
 * The Circle class is a subclass of Oval that interprets for which
 * the constructor interprets its arguments in a different way.  This
 * constructor uses an initialization list to call the Oval constructor
 * with the correct arguments.
 */

Circle::Circle(double x, double y, double r)
          : Oval(x - r, y - r, 2 * r, 2 * r) {
   /* Empty */
}
```

13. Interpreter: Execute the code line by line directly (Python).

    Compiler: transform source code to machine code (binary form) and generate an exe file to execute (C++). Not suitable for cross-platform but has a much higher efficiency than Interpreter.

14. From the textbook:

    1. Read an expression entered by the user into a tree-structured internal form.
    2. Evaluate the tree to compute the expression value.
    3. Print the result of the evaluation on the console.

    This iterated process is called a ***read-eval-print loop.*** Read-eval-print loops are

15. (No need to know in this course)

    1. ***Input.*** The input phase consists of reading in a line of text from the user, which can be accomplished with a simple call to the `getline` function.
    2. ***Lexical analysis.*** The lexical analysis phase consists of dividing the input line into individual units called *tokens,* each of which represents a single logical entity, such as an integer constant, an operator, or a variable name. The `TokenScanner` class from Chapter 6 provides the ideal tool for this phase of the process.
    3. ***Parsing.*** Once the line has been broken down into its component tokens, the parsing phase consists of determining whether the individual tokens represent a legal expression and, if so, what the structure of that expression is. To do so, the parser must determine how to construct a valid parse tree from the individual tokens in the input.

16. An error.

17. the block looks like:

```
try {
    code under the control of the try statement
} catch (type var) {
    code to respond to an exception with the specified value type
}
```

18. /
19. /

20. /
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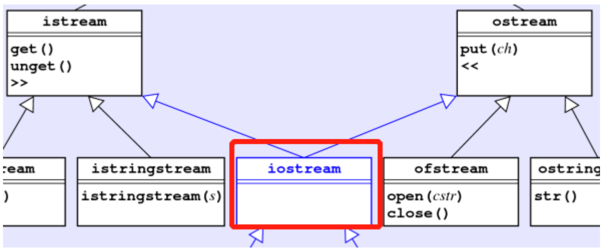
33. /
34. Classes can inherit behavior from more than one superclass



35. F

that can get extremely tricky. One source of trouble, for example, is that the same method or field name can appear in more than one superclass, making it difficult to decide which version to inherit. These problems are sufficiently serious that the creators of Java made an explicit decision not to include multiple inheritance in the language design.

Ch20 Strategies for Iteration

1. ```
   for (Set<int>::iterator it=primes.begin(); it!=primes.end(); it++)
   {cout << *it << endl;}
   ```

2. Return `*it` first and then `it++`; Return the value that iterator points to. Then increment the iterator by 1, now it points to the next element of the collection.

3. T

4. F

5. The `ForwardIterator` class combines these capabilities and supports both reading and writing.

6. F

7. Every function is stored in memory and therefore has an address.

8. The first one is a function that receives a string and returns a `char*`

   The second one is a pointer to the function, where the function receives a string and returns a char.

9. `bool (*fn) (int, int);`
   ```

10. The function serves as the parameter of other functions

    client-supplied function to calculate each new *y* value in the graph. Because the **plot** utility makes a call that crosses back over the abstraction barrier that separates the implementation of **plot** from its caller, the function supplied by the client is called a ***callback function.***

11. From the textbook:

    effect as using an iterator or a range-based **for** loop. Functions that allow you to call a function on every element in a collection are called ***mapping functions.***

12. Function object: any object that overloads the function-call operator. Function pointers: a pointer pointing to a function.
13. `operator()`

    consistent method name for this purpose. Although any method name would do, the most convenient strategy is to have the object itself serve as the method by overloading **operator()**, which defines what it means to "call" an object as a function. In C++, classes that overload this operator are called ***function classes.*** Instances of those classes are called ***function objects*** or ***functors.***

14. `sort(v.begin(), v.end());` arguments are two iterators.
15. From the slides:

    – Programs are expressed in the form of nested function calls that perform the necessary computation without performing any operations (such as assignment) that change the program state.

    – Functions are data values and can be manipulated by the programmer just like other data values.

16. F

    The template class **binary_function<***arg_1***,***arg_2***,***result***>** is the common superclass for all function classes in the **<functional>** library that take two arguments—the first of type *arg_1* and the second of type *arg_2*—and returns a value to type *result*. The class **unary_function<***arg***,***result***>** plays the same role for function classes that take a single argument.

17. The function is:

    Functions that produce function objects

bind1st(*fn***,** *value***)** **bind2nd(***fn***,** *value***)**	Returns a new unary function object that calls the binary function object *fn* with either its first parameter (**bind1st**) or its second parameter (**bind2nd**) bound to *value*.

18. `count_if(v.begin(), v.end(), bind2nd(less<int>(), 0))`
19. The function looks like:

    ```
    bool lessIgnoringCase(string s1, string s2) {
       return toLowerCase(s1) < toLowerCase(s2);
    }
    ```

    you can sort the string vector **names** without regard to case by calling

    ```
    sort(names.begin(), names.end(), lessIgnoringCase());
    ```

20. Define proc as a type "pointer to a function taking no argument and return no result"

    makes a big difference in readability. To reduce this complexity, you can, for example, define the type name **mapCallback** so it is a synonym for the type "pointer to a function taking arguments of type **KeyType** and **ValueType** and returning no result" by including the following line in the definition of the **Map** class:

    ```
    typedef void (*mapCallback)(KeyType, ValueType);
    ```

21. The iterator supports:

RandomAccessIterator	
it + *n*	$it_1 < it_2$
it − *n*	$it_1 <= it_2$
it += *n*	$it_1 > it_2$
it −= *n*	$it_1 >= it_2$
$it_1 - it_2$	

22. F. Iterator acts as pointers.