望月懷遠

海上生明月，
天涯共此時。
情人怨遙夜，
竟夕起相思。
滅燭憐光滿，
披衣覺露滋。
不堪盈手贈，
還寢夢佳期。

～張九齡

Chapter 3

Decisions and Loops

Relational Operators

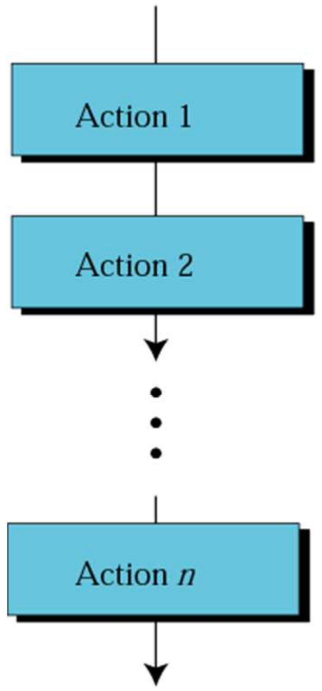
<	Less than
>	Greater than
==	Equal to
<=	Less than or equal to
>=	Greater than or equal to
!=	Not equal to

- Compare the values of two operands, and return
  - true
  - false

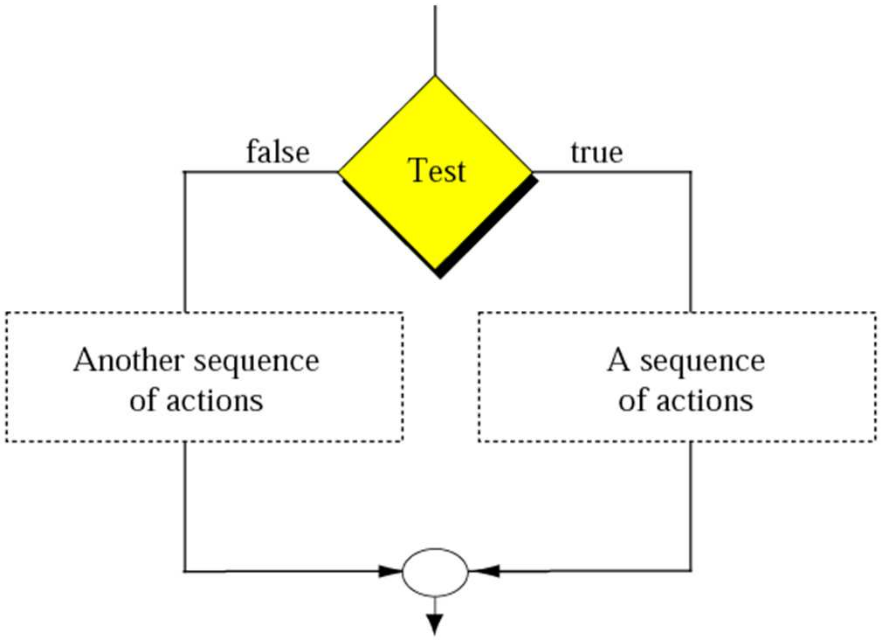
Example of Logical Expressions

- Suppose two integer variables
  i = 10, j = -5
- The following expressions are all true:
  - i > j
  - i != j
  - j > -8
  - i <= j + 15
- cout << (i < j)
  - Displays “0” (implicit type conversion, P.78)
- cout << (i > j)
  - Displays “1” (implicit type conversion)

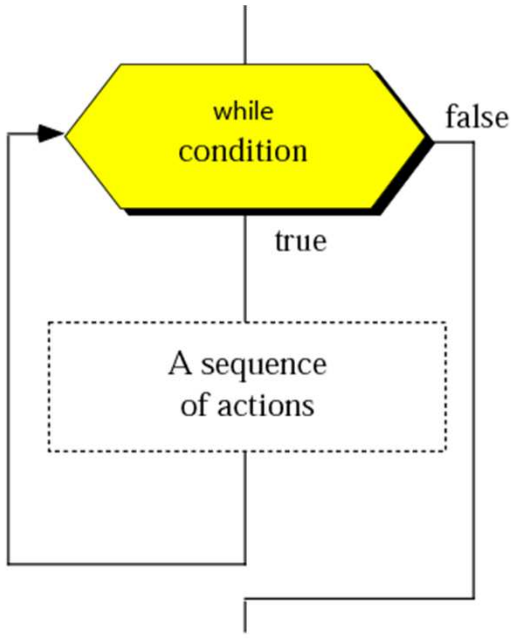
Flowcharts for three constructs



a. Sequence



b. Decision



c. Repetition

The if Statement

- The condition to be tested appears in parenthesis

  -
    ```
    if (letter == 'A')
        cout << "Apple";
    ```
- A block of statements between braces could replace the single statement.

  -
    ```
    if (letter == 'A')
    {
        cout << "Apple";
        letter = 'a';
    }
    ```
- Nested if Statement (P.124)

The if … else … Statement

```
if (number % 2)
    cout << "Odd"
         << endl;
else
    cout << "Even"
         << endl;
```

- The condition express
  - `(number % 2)`
- is equivalent to
  - `(number %2 != 0)`
- A non-zero value is interpreted as `true` (implicit cast).
- A zero value result casts to `false`.

Logical Operators

-
  ```
  if ((letter >= 'A') && (letter <= 'Z'))
     cout << "This is a capital letter.";
  ```

-
  ```
  if ( !(i > 5) )
     cout << "i is not greater than 5\n";
  ```

&&	Logical AND
||	Logical OR
!	Logical negation (NOT)

The Conditional Operator

- `c = a>b ? a : b ;`

  // set c to the maximum of

  // a and b

```
if (a > b)
  c = a;
else
  c = b;
```

- Sometimes called the **ternary operator**.
  - condition ? expression1 : expression2

Output Control

```
cout << endl
     << "We have " << nCakes
     <<  "cake"
     << ((nCakes > 1) ? "s." : ".")
     << endl;
```

- nCakes = 1
  - We have 1 cake.
- nCakes = 2
  - We have 2 cakes.

The switch Statement

```
if (option >= 'a' && option <= 'z')
   switch (option)
   {
     case 'a':
             cout << "Append" << endl;
             break;
     case 'd':
             cout << "Delete" << endl;
             break;
     case 'q':
             cout << "Quit" << endl;
             break;

     default: cout << "You entered a wrong option.";
   }
```

Saves the Trouble of Multiple-if

```
if (option == 'a')
  cout << "Append" << endl;
else
  if (option == 'd')
     cout << "Delete" << endl;
  else
     if (option == 'q')
          cout << "Quit" << endl;
     else
          cout << "You entered a"
               << " wrong option." << endl;
```

Ex3_06.cpp (P.137)

- An elegant example to demonstrate the power of C language.

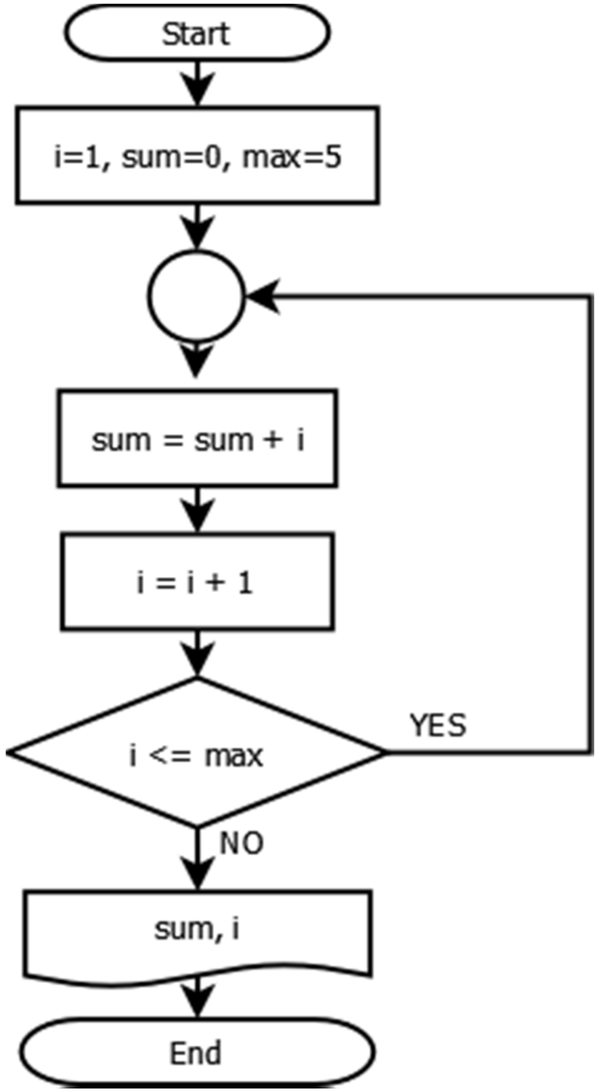
```
switch (letter * (letter >= 'a' && letter <= 'z'))
{
  case 'a':
  case 'e':
  case 'i':
  case 'o':
  case 'u': cout << "You entered a vowel.";
            break;
  case 0: cout << "That is not a small letter.";
            break;
  default: cout << "You entered a consonant.";
}
```

Unconditional Branching

```
myLabel: cout << "myLabel is here";
.
.
.
goto myLabel;
```

- Whenever possible, you should avoid using gotos in your program.

Loop (Ex3_07 in P.139)



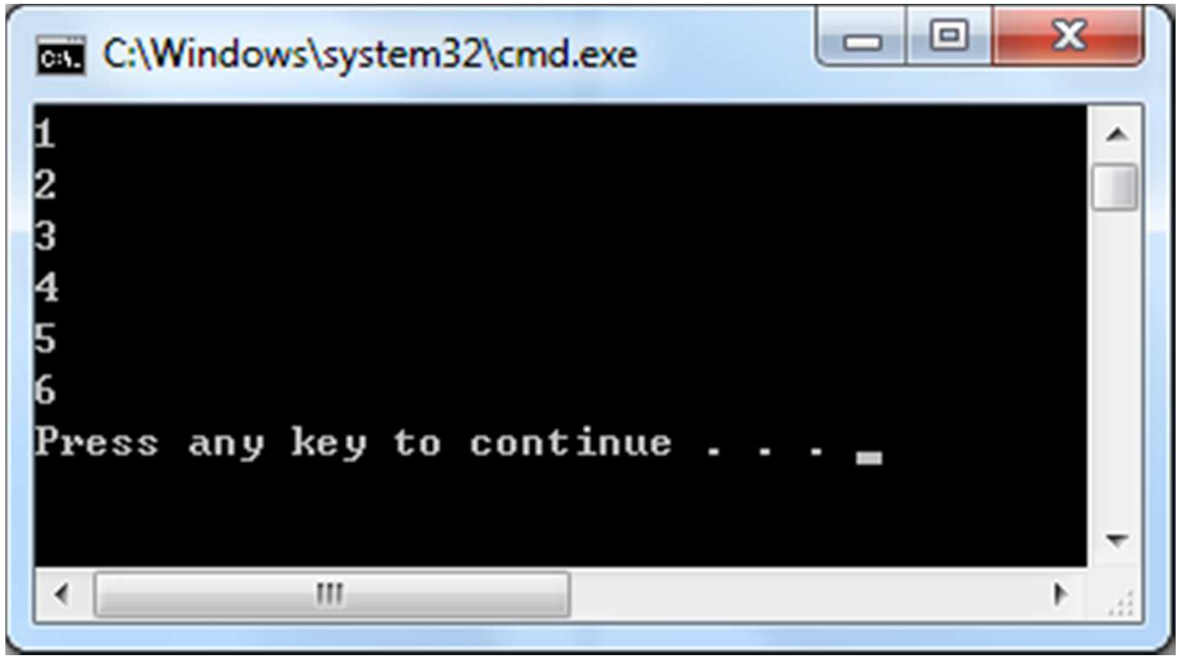
Loop (Ex3_07 in P.139)

```
  int i = 1, sum = 0;
  const int max = 5;

KevinLabel:
  sum +=i;
  if (++i <= max)
     goto KevinLabel;

  cout << "sum=" << sum << endl
     << "i = " << i << endl;
```

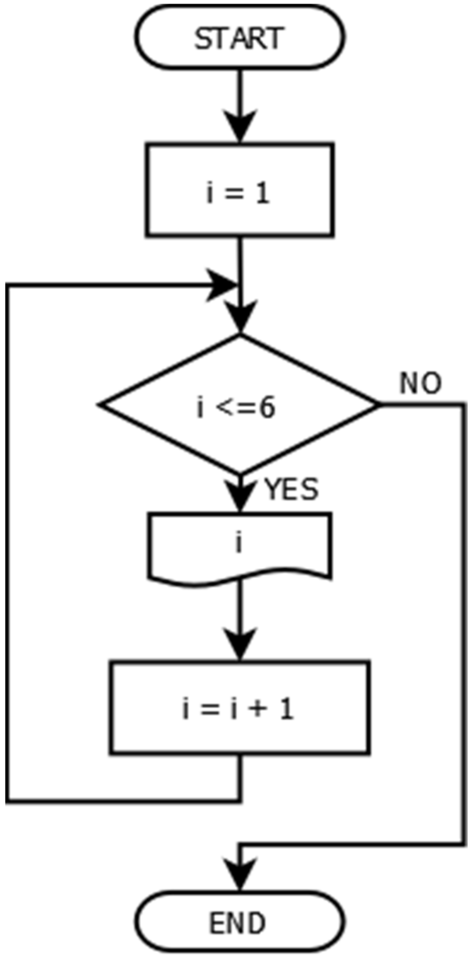
i = [illegible], sum = [illegible]

The for Loop

```
for (i=1; i<=6; i++)
  cout << i << endl;
```

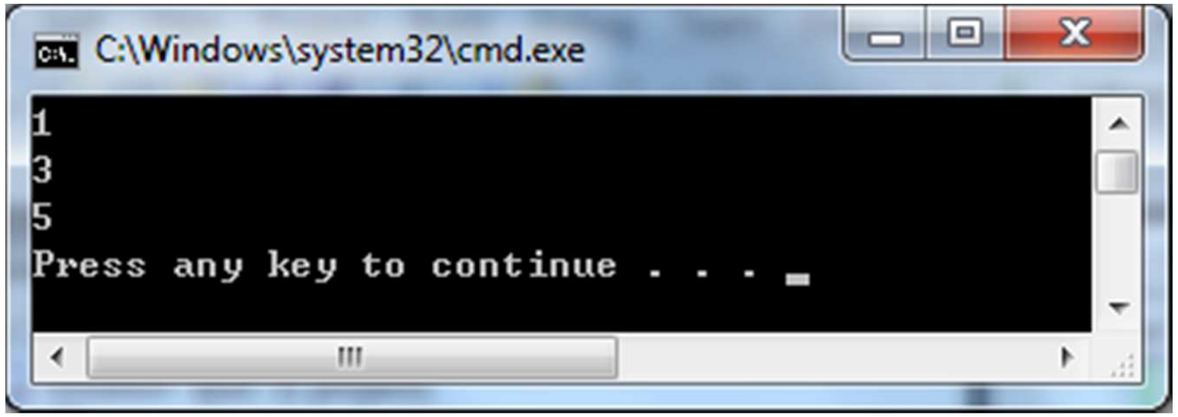


```
1
2
3
4
5
6
Press any key to continue . . .
```

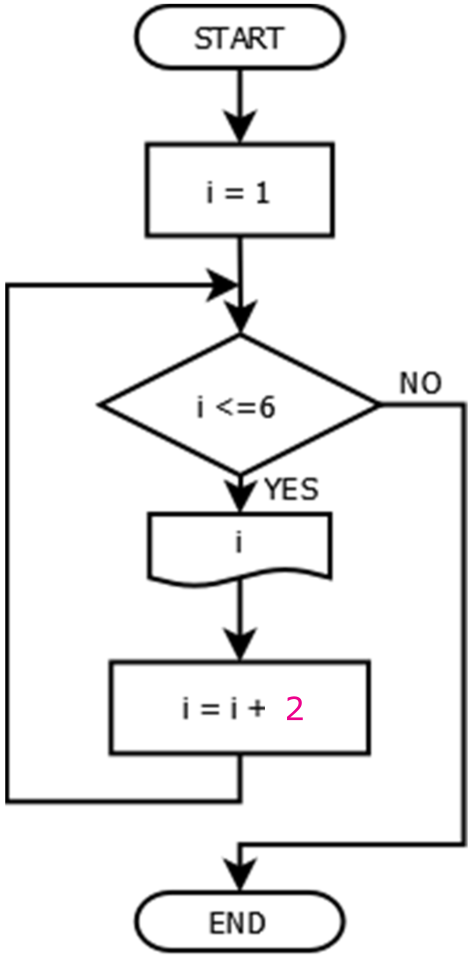


The for Loop (2)

```
for (i=1; i<=6; i+=2)
  cout << i << endl;
```



```
1
3
5
Press any key to continue . . .
```



Using the for Loop for Summation

```
int i = 0, sum = 0;
  const int max = 5;

for (i=1; i<=max; i++)
  sum += i;                    i = 5, sum = 15
```

- General form of the for loop:
  - `for (initializing_expression; test_expression; increment_expression)`
    `loop_statement;`

Nested for Loop

```
const int N = 5;
int i, j;
for (i=1; i<=N; i++)
{
    for (j=1; j<=i; j++)
         cout << '*';
    cout << endl;
}
```

```
*
**
***
****
*****
```

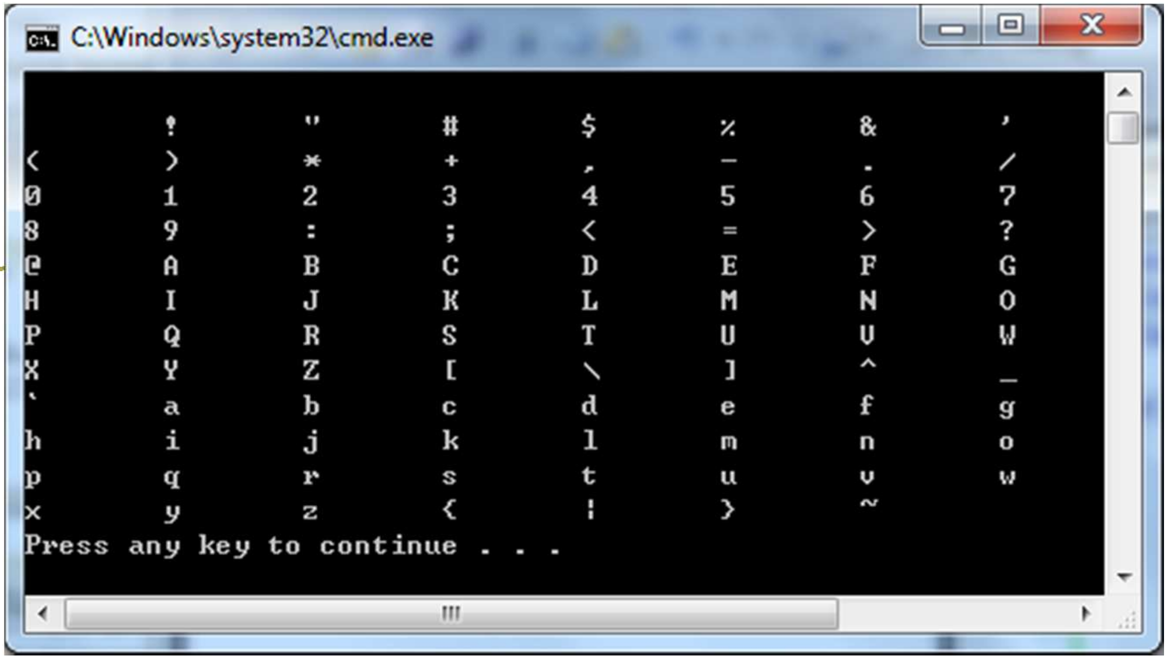
- A block of statements between braces could replace the single *loop_statement*.

Increment/Decrement of the Counter

```
for (i=1; i<=N; i++)
{
    for (j=1; j<=i; j++)
          cout << '*';
    cout << endl;
}

for (i=N; i>=1; i--)
{
    for (j=1; j<=i; j++)
          cout << '*';
    cout << endl;
}
```

```
*
**
***
****
*****
*****
****
***
**
*
```

ASCII Table

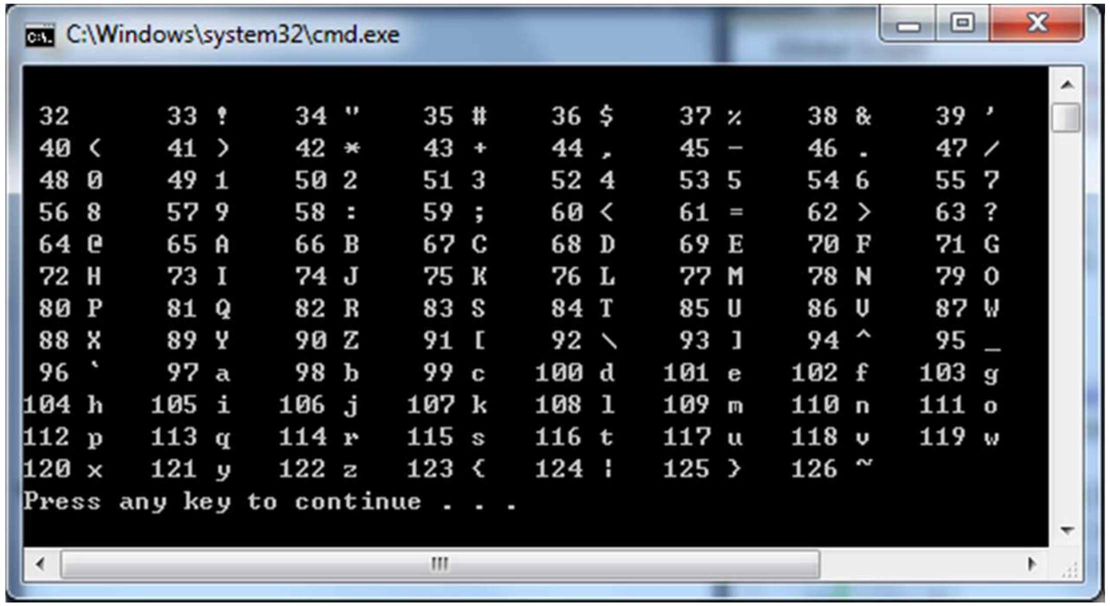


```
        !       "       #       $       %       &       '
(       )       *       +       ,       -       .       /
0       1       2       3       4       5       6       7
8       9       :       ;       <       =       >       ?
@       A       B       C       D       E       F       G
H       I       J       K       L       M       N       O
P       Q       R       S       T       U       V       W
X       Y       Z       [       \       ]       ^       _
`       a       b       c       d       e       f       g
h       i       j       k       l       m       n       o
p       q       r       s       t       u       v       w
x       y       z       {       |       }       ~
Press any key to continue . . .
```

```
#include <iostream>
using std::cout;
using std::endl;

int main()
{
    unsigned char c;
    for (c=32; c<=126; c++)
    {
        if (c % 8 == 0) cout << endl;
        cout << c << '\t';
    }
    cout << endl;
    return 0;
}
```

ASCII Table (2)

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

using std::cout;
using std::endl;
using std::setw;     // P.63

int main()
{
    unsigned char c;
    for (c=32; c<=126; c++)
    {
        if (c % 8 == 0) cout << endl;
        cout << setw(3) << static_cast<int>(c) << ' ';
        cout << c << '\t';
    }
    cout << endl;
    return 0;
}
```



C:\Windows\system32\cmd.exe

```

 32      33 !    34 "    35 #    36 $    37 %    38 &    39 '
 40 (    41 )    42 *    43 +    44 ,    45 -    46 .    47 /
 48 0    49 1    50 2    51 3    52 4    53 5    54 6    55 7
 56 8    57 9    58 :    59 ;    60 <    61 =    62 >    63 ?
 64 @    65 A    66 B    67 C    68 D    69 E    70 F    71 G
 72 H    73 I    74 J    75 K    76 L    77 M    78 N    79 O
 80 P    81 Q    82 R    83 S    84 T    85 U    86 V    87 W
 88 X    89 Y    90 Z    91 [    92 \    93 ]    94 ^    95 _
 96 `    97 a    98 b    99 c   100 d   101 e   102 f   103 g
104 h   105 i   106 j   107 k   108 l   109 m   110 n   111 o
112 p   113 q   114 r   115 s   116 t   117 u   118 v   119 w
120 x   121 y   122 z   123 {   124 |   125 }   126 ~
Press any key to continue . . .
```

Variation on the for Loop

- Declare the counter i within the loop scope. The loop statement can be empty.

  -
    ```
    for (int i = 1; i<=max; sum+= i++)
            ;
    ```
- You can omit the initialization expression

  -
    ```
    int i = 1;
    for (; i <= max; i++)
            sum += i;
    ```
- Use the comma operator (P.75) to specify several expressions:

  -
    ```
    for (i=0, power=1; i<=max; i++, power *=2)
    ```

Summing Up Odd Numbers

```
#include <iostream>
using std::cout;
using std::endl;

int main()
{
      int i;
      int sum=0;
      for (i=1; i<=9; i+=2)
            sum += i;
      cout << sum << endl;
      return 0;
}
```

Prime Number Test

```
#include <iostream>

using std::cin;
using std::cout;
using std::endl;

int main()
{
    int n;
    bool isPrime = true;
    cin >> n;

    if (n % 2 == 0) isPrime = false;
    for (int i=3; i<n; i+=2)
        if (n % i == 0) isPrime = false;
    if (isPrime)
        cout << n << " is a prime number." << endl;
    else
        cout << n << " is NOT a prime number." << endl;
    return 0;
}
```

break vs. continue

- The keyword `continue` allows you to skip the remainder of the current iteration in a loop and go straight to the next iteration.
- The keyword `break` provides an immediate exit from a loop.
- (See P.145 and P.146)

Other Types of Loop

- The while loop

  -
    ```
    while (condition)
       loop_statement;
    ```
  - Ex3_12.cpp on P.151
- The do-while Loop

  -
    ```
    do
    {
       loop_statements;
    } while (condition);
    ```
  - Always executed at least once.
- You may see infinite loops like

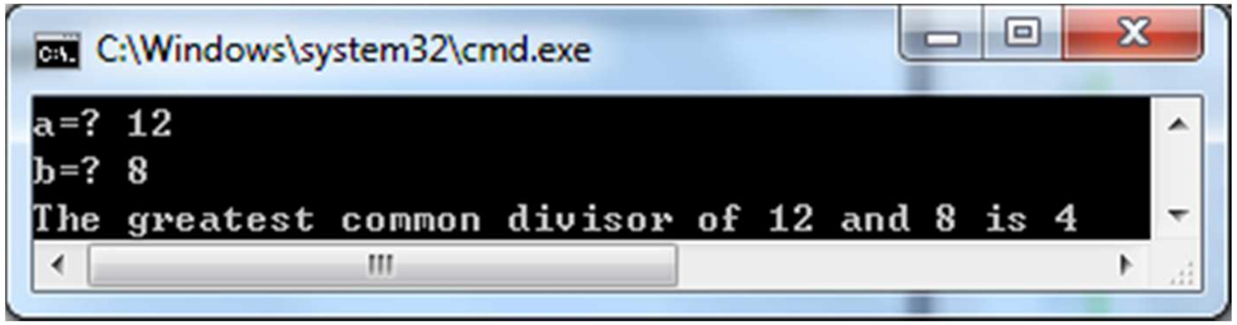
  -
    ```
    while (true)
    {
        …
    }
    ```

  -
    ```
    while (1)
    {
        …
    }
    ```

  -
    ```
    for (;;)
    {
     …
    }
    ```

Greatest Common Divisor

```
#include <iostream>

using std::cin;
using std::cout;
using std::endl;

int main()
{
    int a, b, temp;
    cout << "a=? ";
    cin >> a;
    cout << "b=? ";
    cin >> b;
    if (a==0 && b==0)
    {
        cout << "I don't know how to calculate their gcd.\n";
        return 1;
    }
    cout << "The greatest common divisor of " << a << " and " << b << " is ";
    while (b != 0)
    {
        a %= b;
        temp = b; b = a; a = temp;    // swap a,b
    }
    cout << a << endl;
    return 0;
}
```



```
a=? 12
b=? 8
The greatest common divisor of 12 and 8 is 4
```

Exercise

- Least Common Multiple
  - Input a, b, and output lcm(a,b).
  - For example, lcm(12,8)=24

- You don’t need to upload, but we shall have a quiz at the end of this class.
- Also try to run the sample code introduced in this chapter, to get a feeling about the decisions and loops of C++ language.

Homework (Oct. 12)

- Prime number <= N
  - Extend the “Prime Number Test” program to list all prime numbers less than or equal to N, where N is input from the user.
- Factorization
  - Input N, and factorize N.
  - For example, 12 = 2 * 2 * 3

Homework (bonus)

- Perfect Number
  - In number theory, a **perfect number** is a positive integer that is equal to the sum of its proper positive divisors; that is, the sum of its positive divisors excluding the number itself.
- For example,
  - 6 = 1 + 2 + 3
  - 28 = 1 + 2 + 4 + 7 + 14
- Write a program to list all perfect numbers less than or equal to N, where N is input from the user.