

Ch.4 Variables and Data Types

What you will learn in this chapter



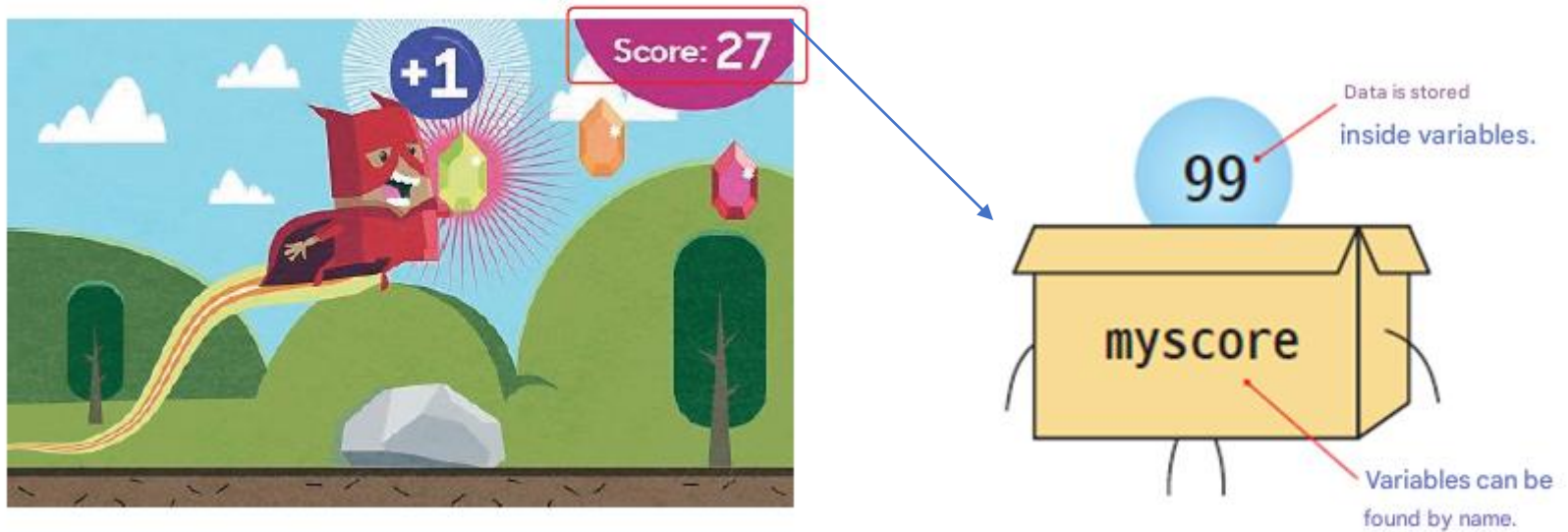
- * Understanding the concept of variables and constants
- * Data type
- * Integer
- * Real number
- * Text type
- * Use symbolic constants
- * Overflow and Understanding Underflow

In this chapter, we will look at variables and various data types .



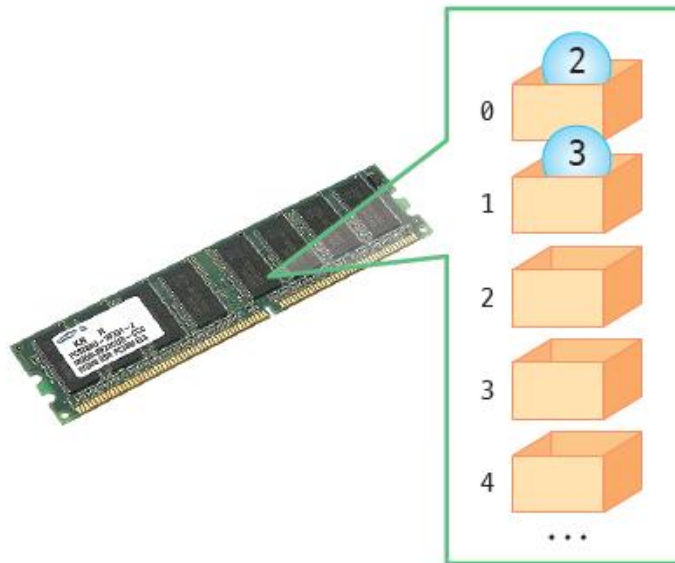
Variable

- Computer programs use variables to store values.
- Variables can be used to store scores in a game, or to store the prices of items we purchased at a supermarket .



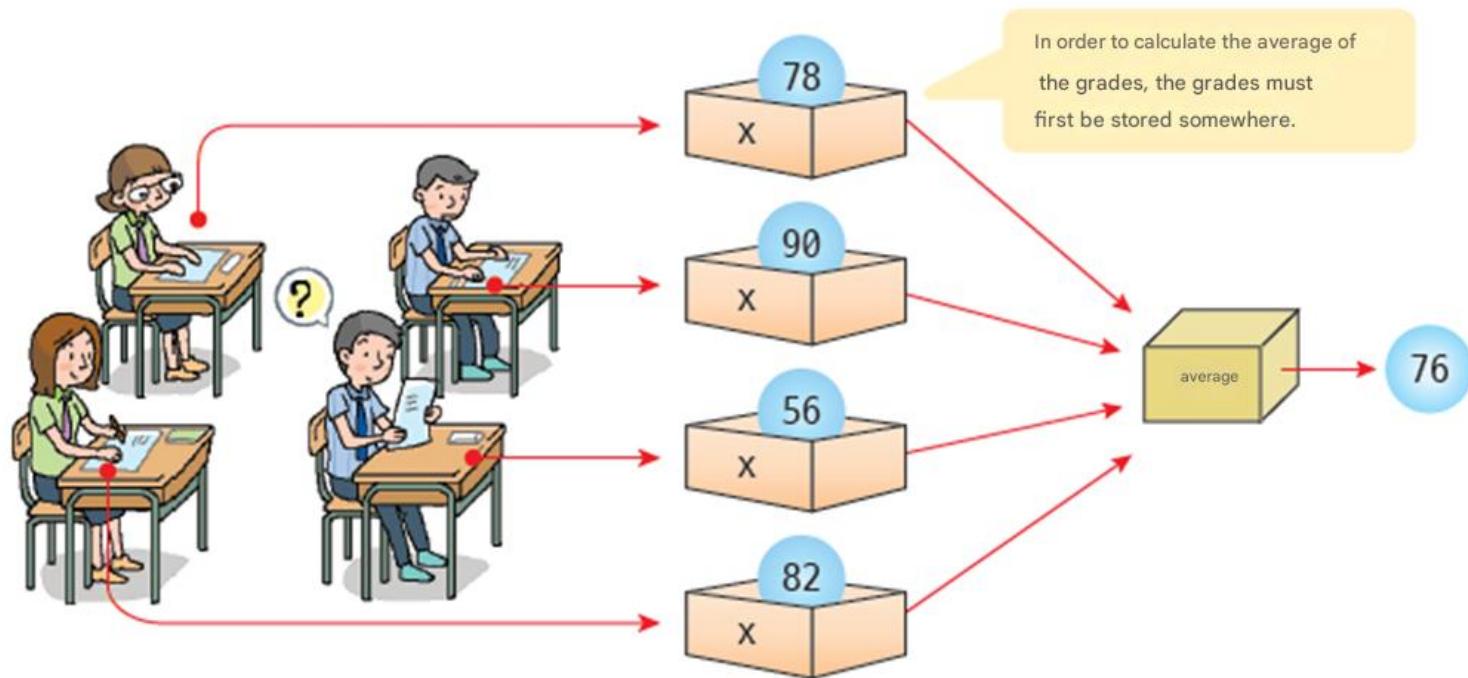
The variable is Where is it made ?

- Variables are created directly in main memory .
- We use memory space by using variable names.



Why do we need variables ? #1

- A place to store data received from users . – If there are no variables, where will the data received from users be stored ?



Why do we need variables ? #2

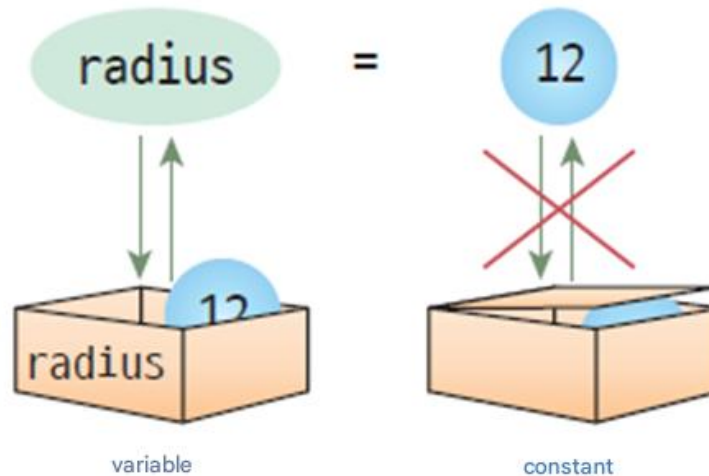
Code that does not use variables	Code that uses variables
<pre>// Area of a square with size 100×200 area = 100 * 200;</pre>	<pre>// Area of a rectangle whose size is width×height width = 100; height = 200; area = width * height;</pre>

Which code is **more flexible**?
Can you adapt better to change?



Variables and Constants

- **Variable** : A space where the stored value can be changed.
- **Constant** : A space where the stored value cannot be changed
 - (Example) 3.14, 100, 'A', “Hello World!”



Variables can change their values during execution.

Constants are values that do not change during execution.

Example : Variables and Constants

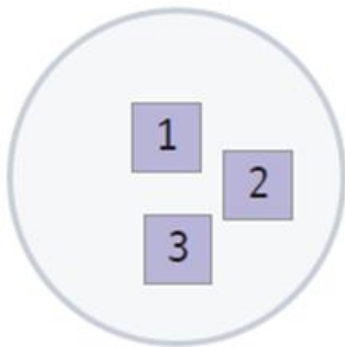
```
/* Program to calculate the area of a circle */  
#include < stdio.h >  
int main( void )  
{  
    float radius; // Radius of the circle  
    float area;  // Area of a circle  
  
    printf ( " Enter the area of the circle : " );  
    scanf ( "%f" , &radius);  
  
    area = 3.141592 * radius * radius;  
    printf ( " Area of the circle : %f \n" , area);  
  
    return 0;  
}
```

Variable

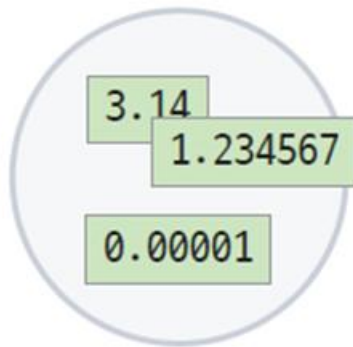
constant

Data type

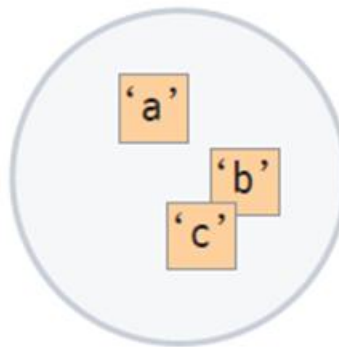
- type : type (kind) of data
 - short, int, long: Integer data (100)
 - double, float: floating point data (3.141592)
 - char: character data ('A', 'a', ' han ')



integer type



floating point type



character type



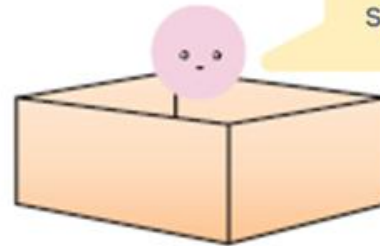
Why we need different data types?

- It's like storing things in boxes .

If the item is larger than the box, it won't fit.

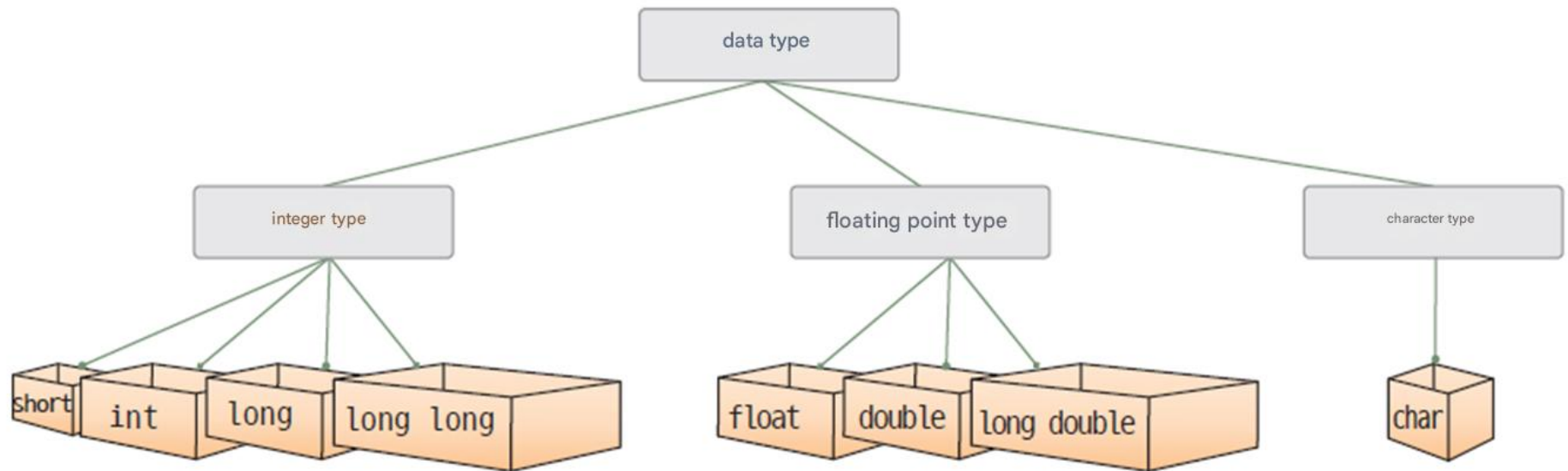


If the item is too small for the box, space will be wasted.



Classification of data types

- Data types can be broadly divided into integer types, floating-point types, and character types .



Size of Data type

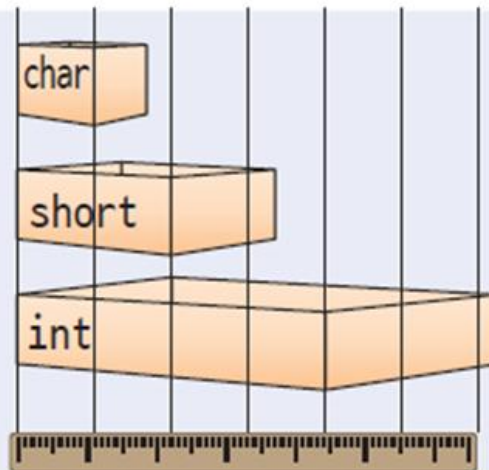
- To find out the size of a data type, use "sizeof" You can use the operator. "sizeof" is an operator that returns the size of a variable or data type in bytes .

Syntax

sizeof()

yes

```
sizeof(x)           // variable  
sizeof(10) // value  
sizeof(int) // data type  
sizeof(double) // data type
```



The sizeof operator returns the size of a variable or data type in bytes.



Example : Size of data type

```
#include <stdio.h>

int main( void )
{
    int x;

    printf ( " Size of variable x : %d\n" , sizeof (x));

    printf ( "Size of char type : %d\n" , sizeof ( char ));
    printf ( " Size of int type : %d\n" , sizeof ( int ));
    printf ( " Size of short type : %d\n" , sizeof ( short ));
    printf ( " Size of long type : %d\n" , sizeof ( long ));
    printf ( " Size of float type : %d\n" , sizeof ( float ));
    printf ( " Size of double type : %d\n" , sizeof ( double ));

    return 0;
}
```

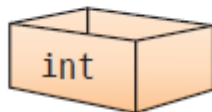
Size of variable x : 4
char type : 1
Size of int type : 4
Short type size : 2
Long type size : 4
Size of float type : 4
Double type size : 8

Integer

data type		bit	range
integer type	short	16 bit	-32768 ~ 32767
	int	32 bit	-2147483648 ~ 2147483647
	long		
	long long	64 bit	-9,223,372,036,854,775,808 ~ 9,223,372,036,854,775,807



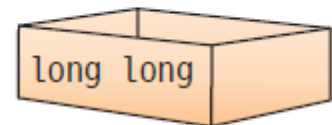
≤



≤



≤



16비트(2바이트)

≤

32비트(4바이트)

≤

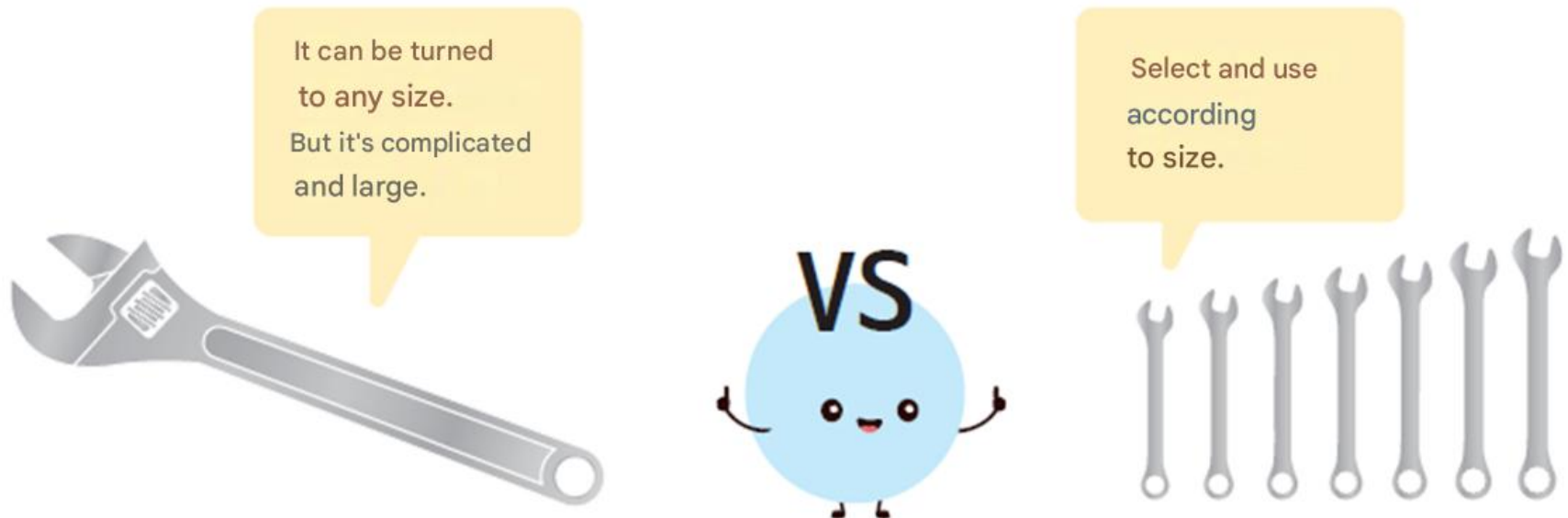
32비트(4바이트)

≤

64비트(8바이트)

Why are there so many different types of integers in C ?

- The idea is to allow programmers to select and use them according to their intended use .
- the number of bits can expand the range of integers, but requires more memory space .



Integer type range

- int type

$-2^{31}, \dots, -2, -1, 0, 1, 2, \dots, 2^{31} - 1$
(-2147483648 ~ +2147483647)

- short type

$-2^{15}, \dots, -2, -1, 0, 1, 2, \dots, 2^{15} - 1$
(-32768 ~ +32767)

- long type


- Usually the same as int type

About -2.1
billion to +2.1
billion



Example

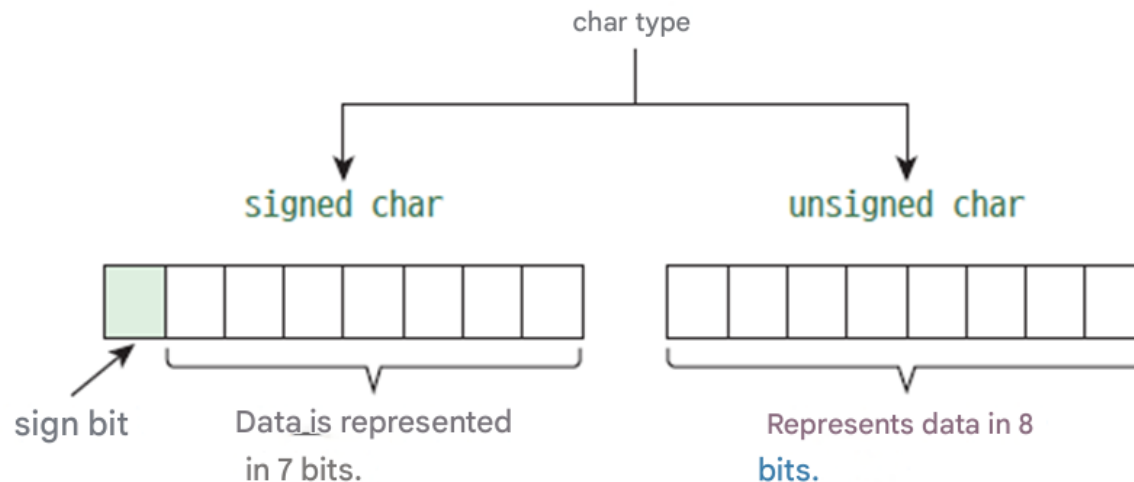
```
/* Program to calculate the size of an integer data type */  
#include < stdio.h >  
  
int main( void )  
{  
    short year = 0; // Initialize to 0 .  
    int sale = 0; // Initialize to 0 .  
    long total_sale = 0; // Initialize to 0 .  
    long long large_value ; // 64- bit data type  
  
    year = 10; // Be careful not to exceed about 32,000  
    sale = 2000000000; // Be careful not to exceed about 2.1 billion  
    total_sale = year * sale; // Be careful not to exceed about 2.1 billion  
  
    printf ( " total_sale = %d \n" , total_sale );  
  
    return 0;  
}
```



total_sale = 2000000000

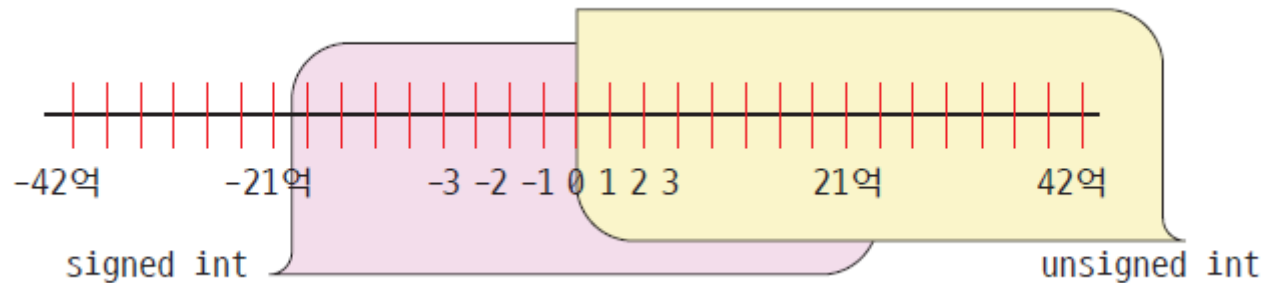
signed, unsigned modifiers

- unsigned
 - Means that only non-negative values are represented
 - unsigned int
- signed
 - Means that it represents a value with a sign
 - Commonly omitted



unsigned int

$0, 1, 2, \dots, 2^{32} - 1$
(0 ~ +4294967295)



unsigned example

```
unsigned int speed; // unsigned int type  
unsigned distance; // unsigned int distance and It's the same .  
unsigned short players; // unsigned short type
```

```
unsigned int sales = 2800000000; // about 2.8 billion  
printf ( " %u \n" , sales); // If you use %d , it will be printed as a negative number
```

unsigned uses
%u to print it out .



Overflow

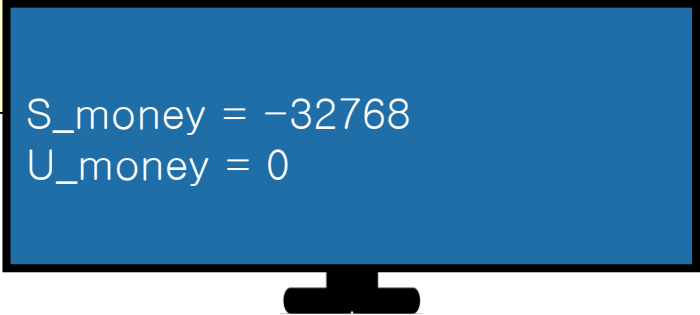
```
#include <stdio.h>
#include <limits.h>

int main( void )
{
    short s_money = SHRT_MAX; // Initialize to maximum value . 32767
    unsigned short u_money = USHRT_MAX; // Initialize to maximum value . 65535

    s_money = s_money + 1;
    printf ( " s_money = %d" , s_money );

    u_money = u_money + 1;
    printf ( " u_money = %d" , u_money );
    return 0;
}
```

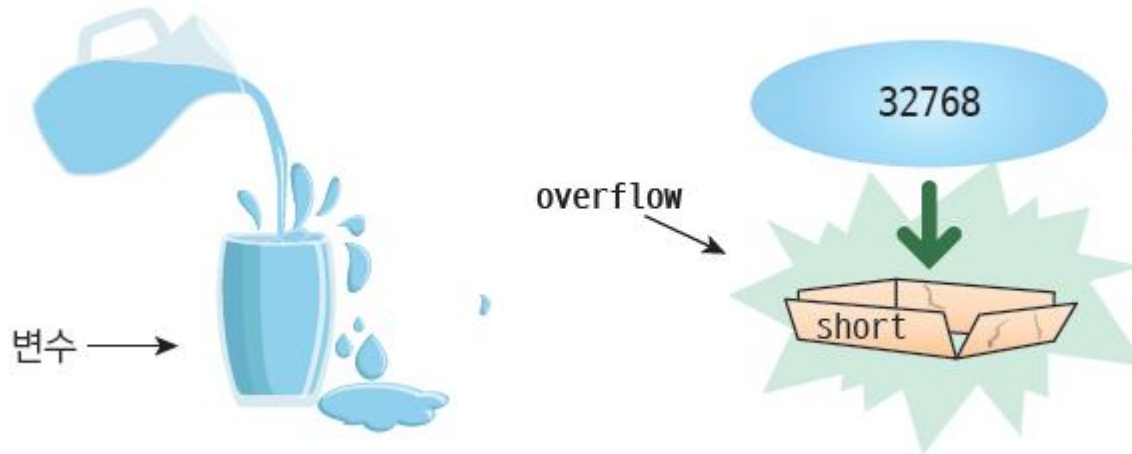
Overflow occurred !!



S_money = -32768
U_money = 0

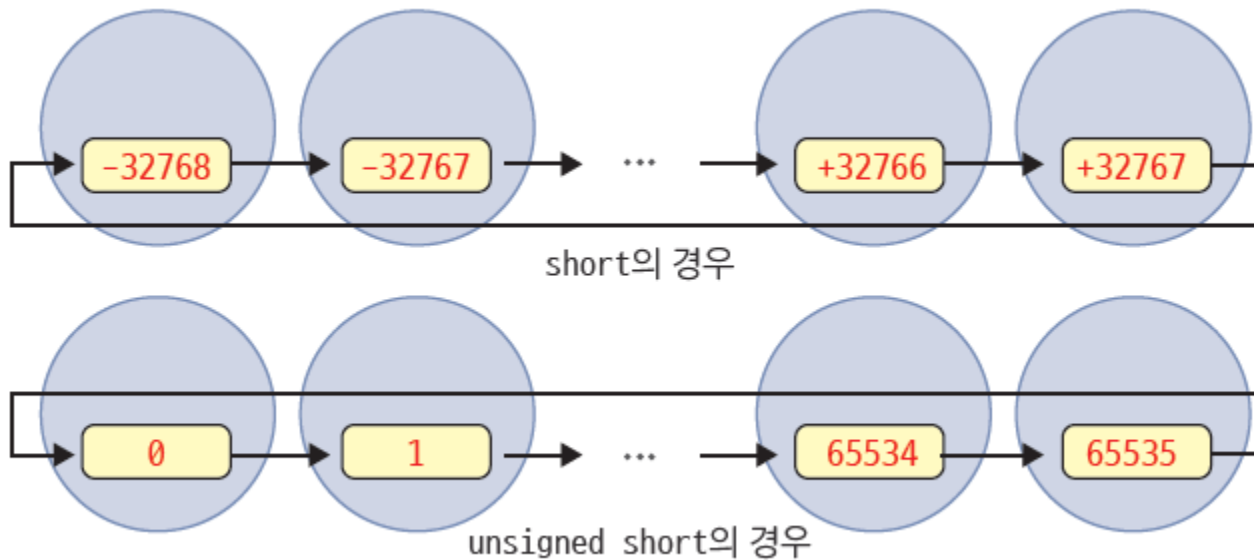
Overflow

- **Overflow** : Occurs when you try to store a number that exceeds the range that a variable can represent



Overflow

- There is a pattern .
 - It works similarly to a water meter or a car odometer.



reference

Note

The maximum and minimum values for each data type are defined in limits.h.

```
#define CHAR_MIN    (-128)
#define CHAR_MAX    127

#define SHRT_MIN    (-32768)    /* minimum (signed) short value */
#define SHRT_MAX    32767      /* maximum (signed) short value */
#define USHRT_MAX   0xffff     /* maximum unsigned short value */

#define INT_MIN     (-2147483647 - 1) /* minimum (signed) int value */
#define INT_MAX     2147483647      /* maximum (signed) int value */
#define UINT_MAX    0xffffffff     /* maximum unsigned int value */
```


Integer constant

- Basically, when you write a number, It becomes int type .
 - `sum = 123; // 123 is int type`
- the data type of a constant, do the following :
 - `sum = 123L; // 123 is long type`

suffix	data type	yes
u or U	unsigned int	123u or 123U
l or L	long	123l or 123L
ul or UL	unsigned long	123ul or 123UL

Decimal , octal , hexadecimal

- Octal

- $012_8 = 1 \times 8^1 + 2 \times 8^0 = 10$

- Hexadecimal

- $0xA_{16} = 10 \times 16^0 = 10$

decimal	octal	hexadecimal
0	00	0x0
1	01	0x1
2	02	0x2
3	03	0x3
4	04	0x4
5	05	0x5
6	06	0x6
7	07	0x7
8	010	0x8
9	011	0x9
10	012	0xa
11	013	0xb
12	014	0xc
13	015	0xd
14	016	0xe
15	017	0xf
16	020	0x10
17	021	0x11
18	022	0x12

Example

```
/* Integer constant program */  
#include <stdio.h>  
  
int main( void )  
{  
    int x = 10; // 10 is a decimal number, is of type int , and has a value of 10 in decimal .  
    int y = 010; // 010 is an octal number, of type int , and its value is 8 in decimal .  
    int z = 0x10; // 010 is a hexadecimal number, int type, and its value is 16 in decimal .  
  
    printf ( "x = %d" , x);  
    printf ( "y = %d" , y);  
    printf ( "z = %d" , z);  
  
    return 0;  
}
```

x = 10
y = 8

x = 10
y = 8
z = 16

Symbolic Constant

- constant : A constant expressed using symbols.
- (example)
 - won = 1120 * dollar; // (1) Use actual value
 - won = EXCHANGE_RATE * dollar; // (2) Use of symbolic constants
- Advantages of symbolic constants
 - Readability is improved .
 - The values can be easily changed .

Advantages of symbolic constants

```
#include <stdio.h>
```

```
int main(void)
```

```
{
```

```
...
```

```
won1 = 1120 * dollar1;
```

```
won2 = 1120 * dollar2;
```

```
...
```

```
}
```

1050

1050

When using literal constants:

Every place it appears must be corrected.

```
#include <stdio.h>
```

```
#define EXCHANGE_RATE 1120
```

```
int main(void)
```

```
{
```

```
...
```

```
won1 = EXCHANGE_RATE * dollar1;
```

```
won2 = EXCHANGE_RATE * dollar2;
```

```
...
```

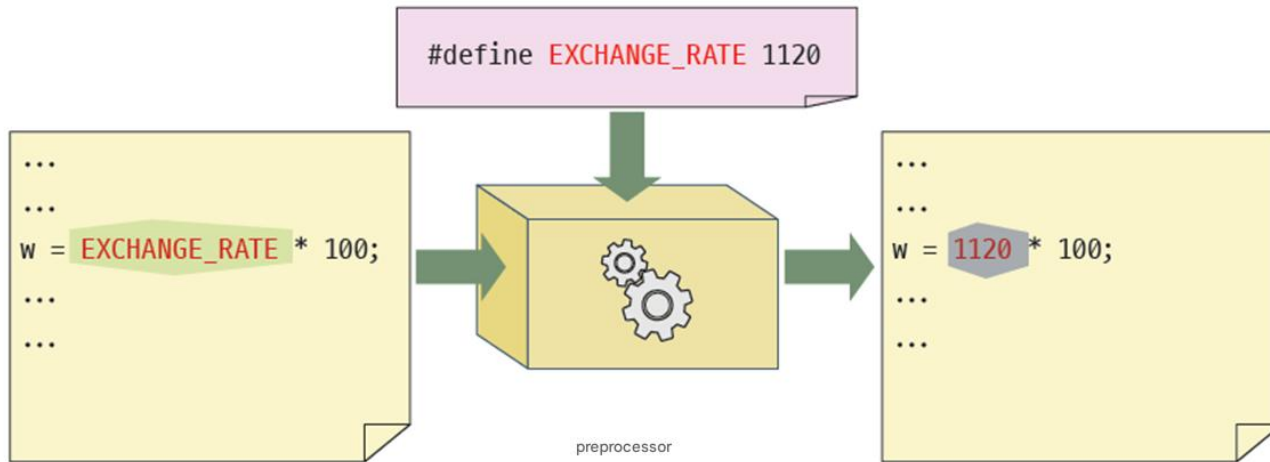
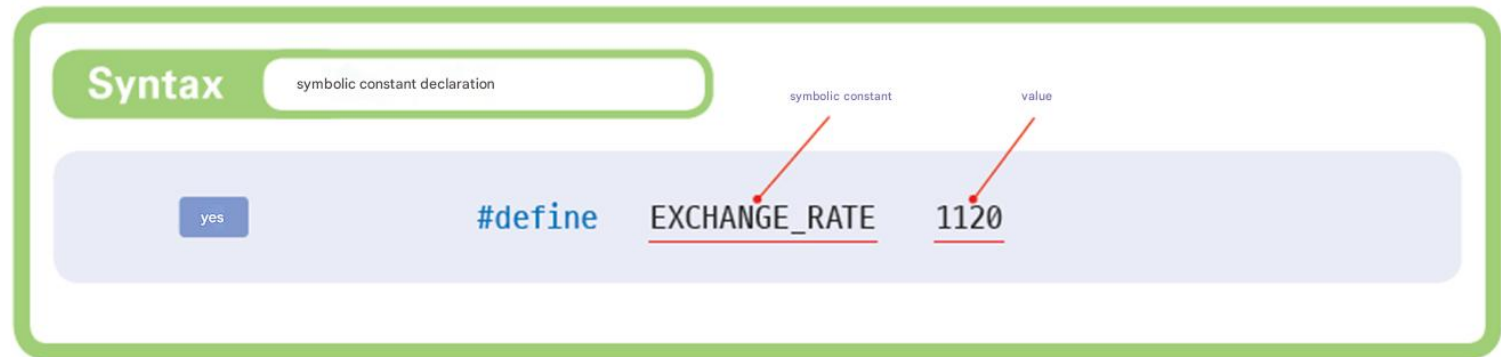
```
}
```

1050

When using symbolic constants:

You only need to modify the places where symbolic constants are defined.

How to create symbolic constants #1



How to create symbolic constants #2

Syntax

symbolic constant declaration

yes

```
const int EXCHANGE_RATE = 1120;
```

symbolic constant

value

Example : Symbolic Constants

```
#include <stdio.h>
```

```
#define TAX_RATE 0.2
```

Symbol constant

```
int main( void )
```

```
{
```

```
    const int MONTHS = 12;
```

```
    int m_salary , y_salary ; // Declare variables
```

```
    printf ( " Enter your salary : " ); // Input instructions
```

```
    scanf ( "%d" , & m_salary );
```

```
    y_salary = MONTHS * m_salary ; // Calculate net income
```

```
    printf ( " Your annual salary is %d ." , y_salary );
```

```
    printf ( " Tax is %f ." , y_salary *TAX_RATE);
```

```
    return 0;
```

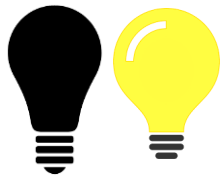
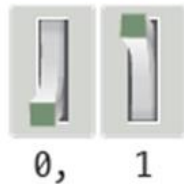
```
}
```

*Enter your salary : 100
The annual salary is 1200 .
The tax is 240.000000 .*

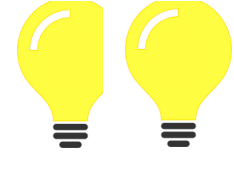
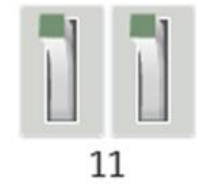
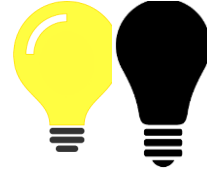
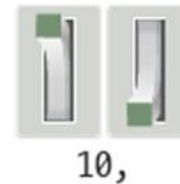
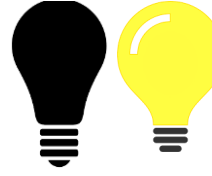
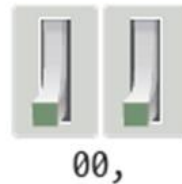
Integer representation method

- In computers, integers are represented in binary form, and binary numbers are represented by electronic switches .

If there is a switch



If there are two switches

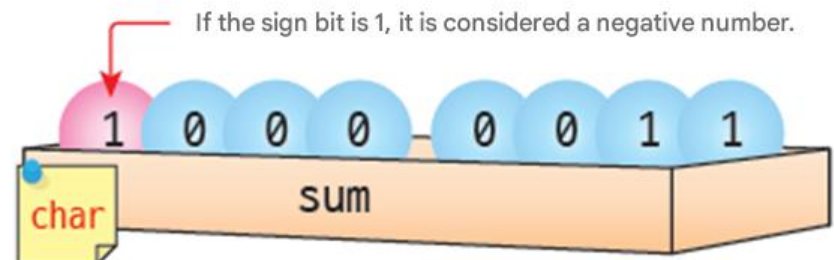
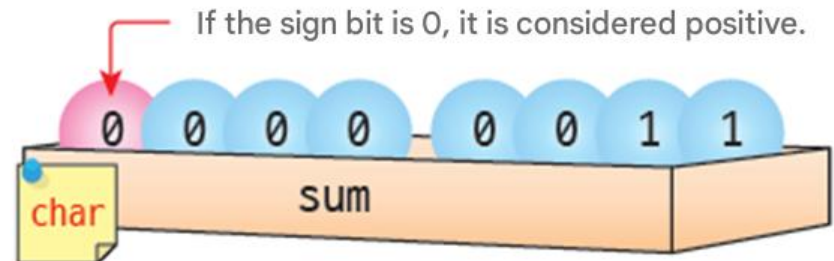


short type

beat pattern	integer	note
0000000000000000	0	positive integer
0000000000000001	1	
0000000000000010	2	
0000000000000011	3	
0000000000000100	4	
0000000000000101	5	
...	...	

Integer representation method

- Positive
 - You can convert decimal to binary and save it .
- negative
 - Usually the first bit is used as the sign bit .
 - A problem arises .



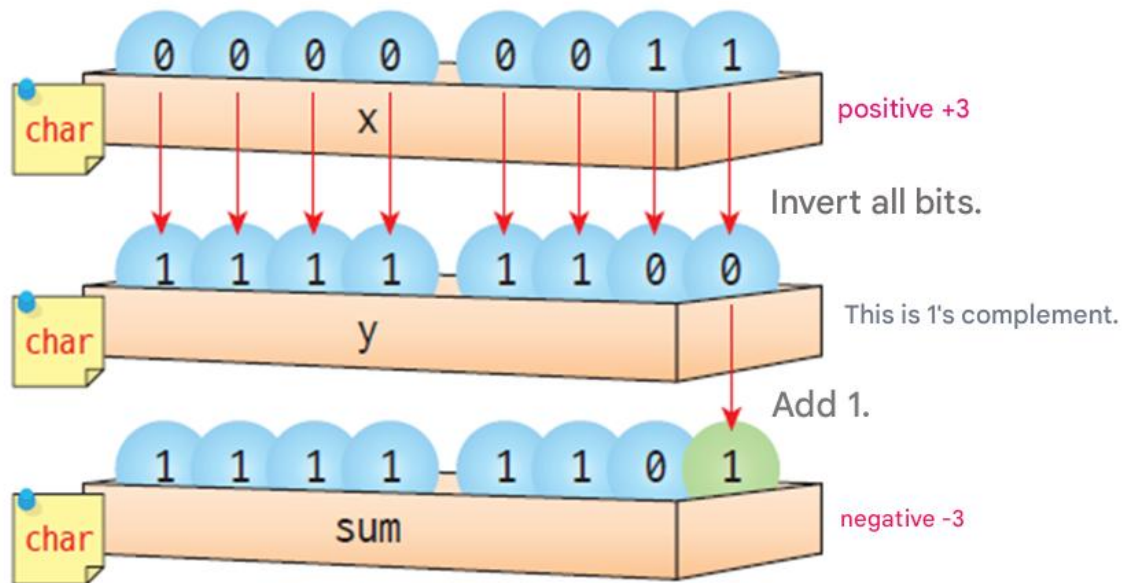
Computers can only do addition

- Computers only have addition circuits to reduce the size of the circuit .
- Subtraction is converted to addition as follows: Handle it.

$$3-3 \Rightarrow 3+(-3)$$

Way to express negative numbers

- Representing negative numbers with 2 's complement
-> Standard way to represent negative numbers
- 2 's complement



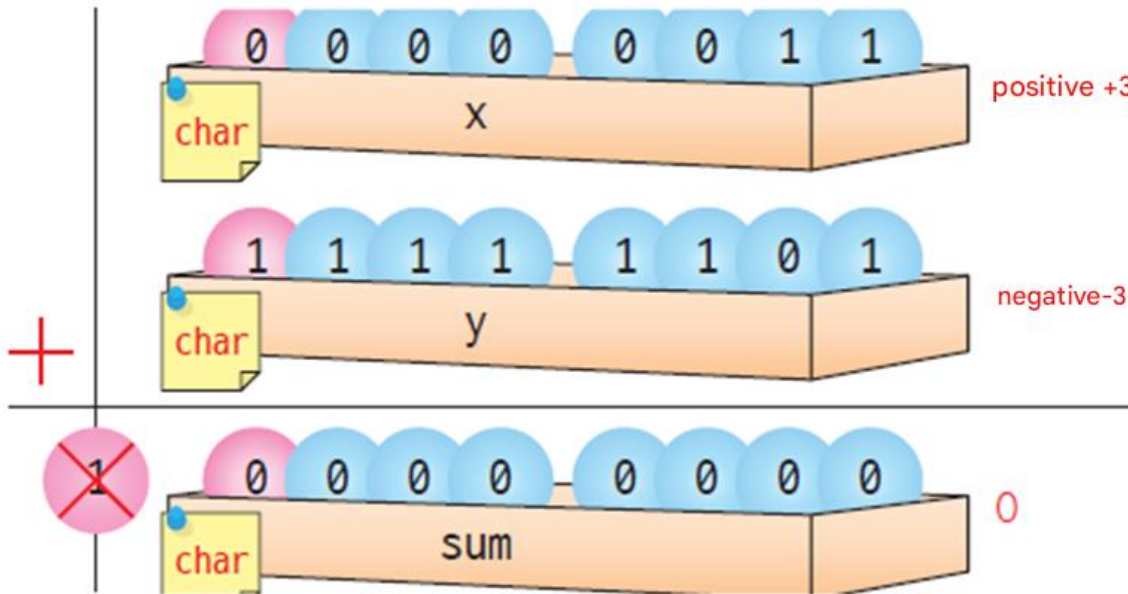
2 's complement

<https://www.rapidtables.com/convert/number/decimal-to-binary.html?>

bit	unsigned integer	Signed integer (2's complement)
000	0	0
001	1	1
010	2	2
011	3	3
100	4	-4
101	5	-3
110	6	-2
111	7	-1

bit	unsigned integer	Signed integer (2's complement)
0000 0000	0	0
0000 0001	1	1
0000 0010	2	2
0111 1110	126	126
0111 1111	127	127
1000 0000	128	-128
1000 0001	129	-127
1000 0010	130	-126
1111 1110	254	-2
1111 1111	255	-1

2 's complement,



negative numbers in 2 's complement, you can add positive and negative numbers by adding the individual bits .



Example

```
/* 2's complement program */  
#include <stdio.h>
```

```
int main( void )  
{
```

```
    int x = 3;
```

```
    int y = -3;
```

negative numbers are
represented in 2's
complement .

```
    printf ( "x = %08X\n" , x); // Print as 8 - digit hexadecimal number .
```

```
    printf ( "y = %08X\n" , y); // Print as 8- digit hexadecimal number .
```

```
    printf ( " x+y = %08X\n" , x+y ); // Print as 8 - digit hexadecimal number .
```

```
    return 0;
```

```
}
```

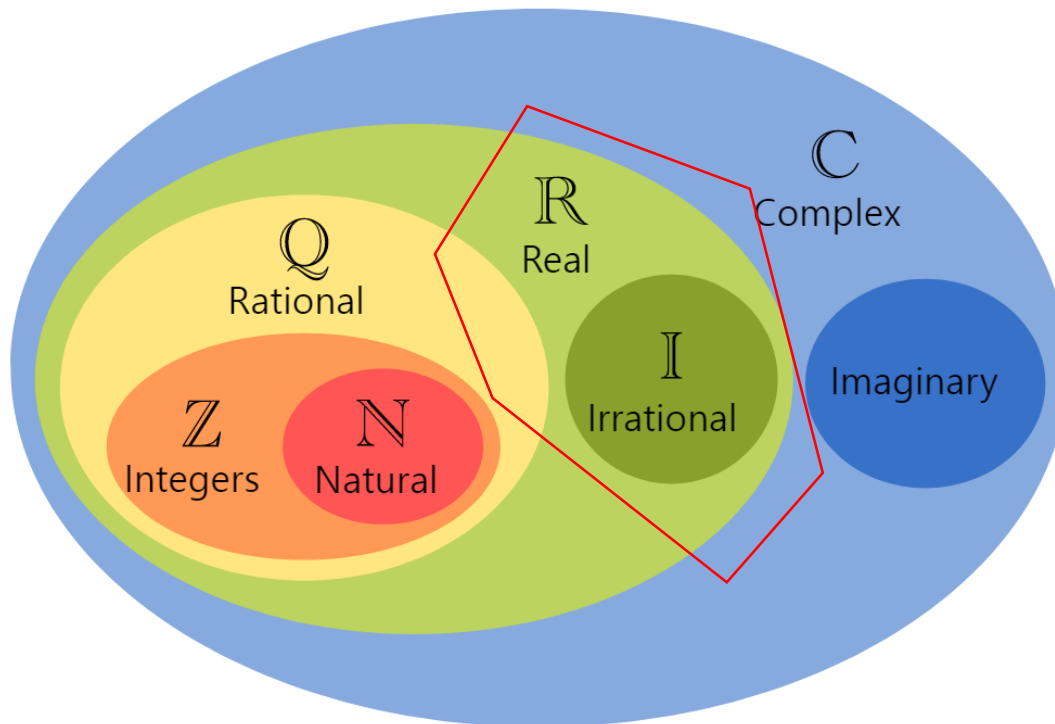
x = 00000003

y = FFFFFFFD

x+y = 00000000

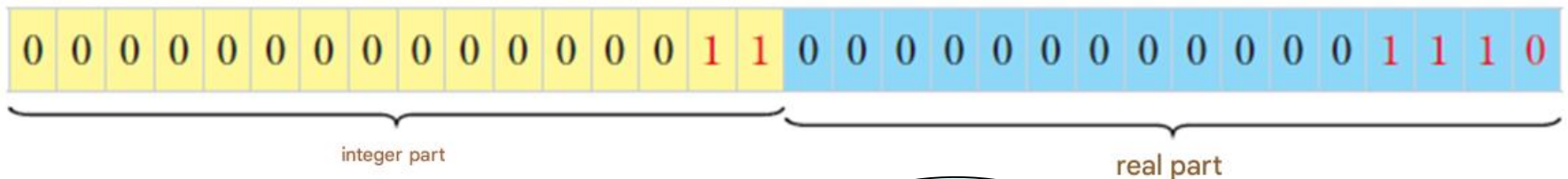
How to indicate a real number

- In mathematics, a real number is a number with a decimal point, such as 3.14. Real numbers are an essential element when writing applications in science or engineering that deal with very large or very small numbers .



How to Express a real number #1

- Allocate a certain number of bits for the integer part and a certain number of bits for the fractional part.
- The total is 32 bits , 16 bits are allocated for the integer part and 16 bits for the fractional part .
- It cannot express the very large numbers required in science and engineering.

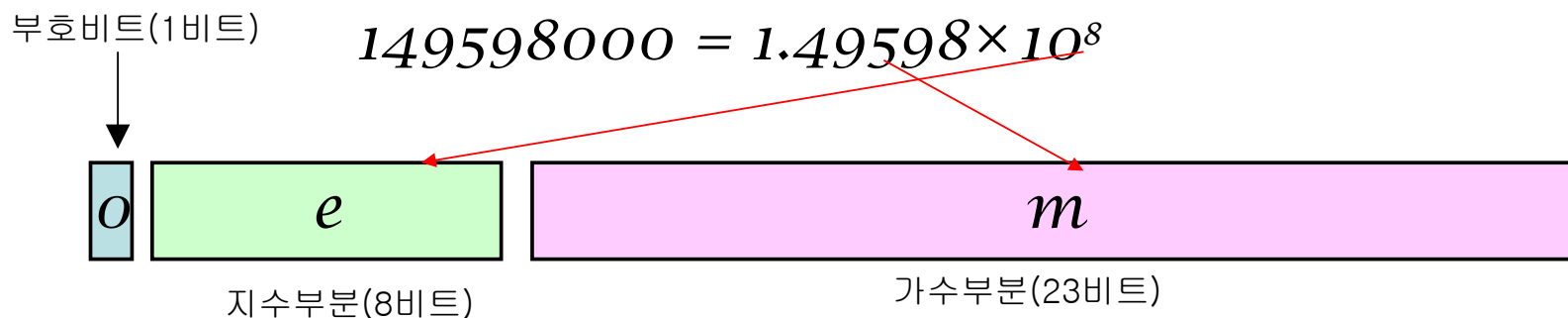


What is the largest number that can be represented this way ?



How to Express a real number #2

- Floating point method



$$\text{실수값} = (-1)^s * (1.m) * 2^{e-127}$$

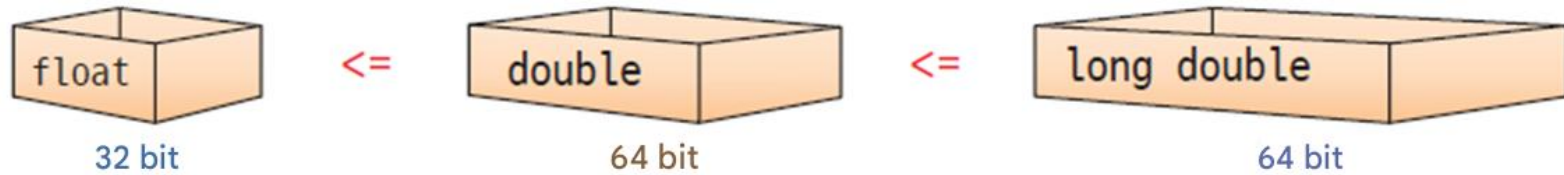
$$\text{Value} = \text{Sign} \times \text{Mantissa} \times 2^{\text{Exponent}}$$

- The range of expressions available is greatly expanded
- 10^{-38} 10^{+38} at

There have been a number of different floating point methods in use for some time, but they have been standardized since 1985 as IEEE 754 .



Floating point type



data type	designation	size	range
float	single-precision floating point	32 bit	$\pm 1.17549 \times 10^{-38} \sim \pm 3.40282 \times 10^{+38}$
double long double	double-precision floating point	64 bit	$\pm 2.22507 \times 10^{-308} \sim \pm 1.79769 \times 10^{+308}$

Format specifier for printing real numbers

- %f
 - `printf ("%f", 0.123456789); // Prints 0.123457`
- %e
 - `printf ("%e", 0.123456789); // Prints 1.234568e-001`

Example

```
/* Calculating the size of floating point data types */  
#include <stdio.h>  
int main( void )  
{  
    float x = 1.234567890123456789;  
    double y = 1.234567890123456789;  
  
    printf ( " Size of float =%d\n" , sizeof ( float ));  
    printf ( " Size of double =%d\n" , sizeof ( double ));  
  
    printf ( "x = %30.25f\n" ,x );  
    printf ( "y = %30.25f\n" ,y );  
    return 0;  
}
```

```
size of float = 4  
size of double =8  
x = 1.23456788063049320000000000  
y = 1.23456789012345670000000000
```

Floating point constant

mistake	exponential notation	meaning
123.45	1.2345e2	1.2345×10^2
12345.0	1.2345e4	1.2345×10^4
0.000023	2.3e-5	2.3×10^{-5}
2,000,000,000	2.0e9	2.0×10^9

1.23456

2.

// You can just add a decimal point.

.28

// The integer part is not required.

2e+10

// + or - signs can be added to the exponent.

9.26E3

// 9.26×10^3

0.67e-9

// 0.67×10^{-9}

Floating point overflow

```
#include <stdio.h>
```

```
int main( void )
```

```
{
```

```
float x = 1e39;
```

```
printf ( "x = %e\ n" ,x );
```

```
}
```

Overflow occurs due to large number

x = inf

Press any key to continue . . .

Floating point underflow

```
#include <stdio.h>
```

```
int main( void )
```

```
{
```

```
    float x = 1.23456e-38;
```

```
    float y = 1.23456e-40;
```

```
    float z = 1.23456e-46;
```

Underflow occurs

```
    printf( "x = %e\n" ,x);
```

```
    printf( "y = %e\n" ,y);
```

```
    printf( "z = %e\n" ,z);
```

```
}
```

x = 1.234560e-038

y = 1.234558e-040

z = 0.000000e+000

Cautions when using floating point numbers

- There may be errors !

```
#include <stdio.h>
```

```
int main( void )
```

```
{
```

```
    float value = 0.1;
```

```
    printf ( "%.20f \n" , value);
```

```
    return 0;
```

```
}
```

This is because there are values that cannot be represented exactly in binary . 0.1 is one of them .

// %.20f means to print with 20 decimal places .

0.10000000149011611938

Precautions when using floating point numbers

- There may be errors !

```
#include <stdio.h>
```

```
int main( void )
```

```
{
```

```
    double x;
```

```
    x = (1.0e20 + 5.0)-1.0e20;
```

```
    printf( "%f \n" ,x);
```

```
    return 0;
```

```
}
```

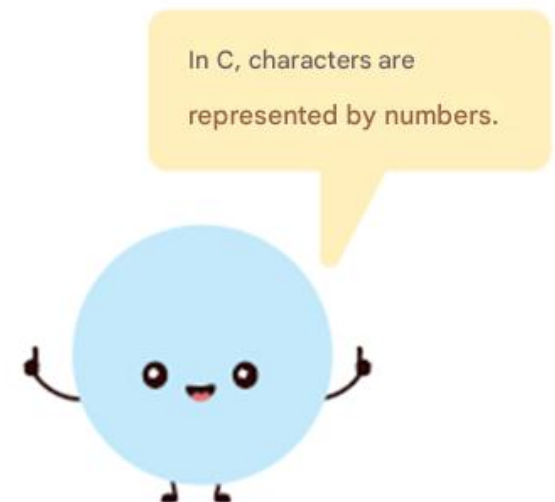
Floating point operations introduce errors .

It is calculated as 0 , not 5.0 .

0.000000

Text type

- Text is more important to humans than to computers
- Letters are also expressed using numbers
- A common standard is needed .
- ASCII code (**ASCII**: American Standard Code for Information Interchange)



ASCII Code table (some)

Dec	Hex	문자	Dec	Hex	문자	Dec	Hex	문자	Dec	Hex	문자
0	0	NULL	20	14	DC4	40	28	(60	3C	<
1	1	SOH	21	15	NAK	41	29)	61	3D	=
2	2	STX	22	16	SYN	42	2A	*	62	3E	>
3	3	ETX	23	17	ETB	43	2B	+	63	3F	?
4	4	EOL	24	18	CAN	44	2C	,	64	40	@
5	5	ENQ	25	19	EM	45	2D	-	65	41	A
6	6	ACK	26	1A	SUB	46	2E	.	66	42	B
7	7	BEL	27	1B	ESC	47	2F	/	67	43	C
8	8	BS	28	1C	FS	48	30	0	68	44	D
9	9	HT	29	1D	GS	49	31	1	69	45	E
10	A	LF	30	1E	RS	50	32	2	70	46	F
11	B	VT	31	1F	US	51	33	3	71	47	G
12	C	FF	32	20	space	52	34	4	72	48	H
13	D	CR	33	21	!	53	35	5	73	49	I
14	E	S0	34	22	"	54	36	6	74	4A	J
15	F	SI	35	23	#	55	37	7	75	4B	K
16	10	DLE	36	24	\$	56	38	8	76	4C	L
17	11	DC1	37	25	%	57	39	9	77	4D	M
18	12	DC2	38	26	&	58	3A	:	78	4E	N
19	13	DC3	39	27	'	59	3B	;	79	4F	O

ASCII Code table (some)

Dec	Hex	문자
80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\
93	5D]
94	5E	^
95	5F	_
96	60	`
97	61	a
98	62	b
99	63	c

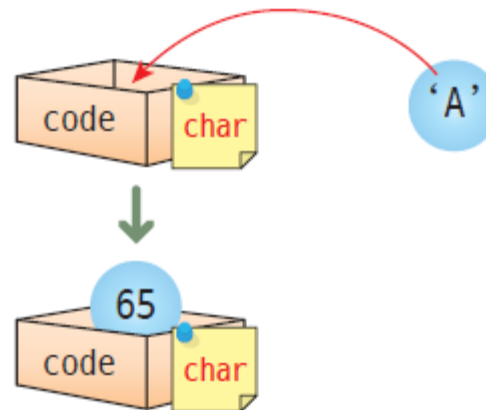
Dec	Hex	문자
100	64	d
101	65	e
102	66	f
103	67	g
104	68	h
105	69	i
106	6A	j
107	6B	k
108	6C	l
109	6D	m
110	6E	n
111	6F	o
112	70	p
113	71	q
114	72	r
115	73	s
116	74	t
117	75	u
118	76	v
119	77	w

[illegible]

Character variable

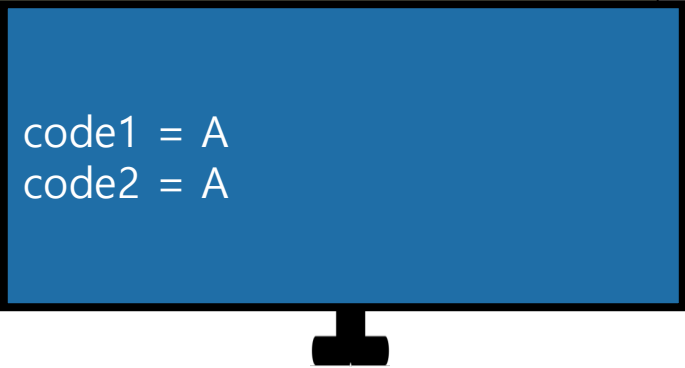
- char type Use to store text .

```
char code;  
code = 'A' ;
```



Example

```
/* Character variables and character constants */  
#include <stdio.h>  
  
int main( void )  
{  
    char code1 = 'A' ; // Initialize to a character constant  
    char code2 = 65; // Initialize to ASCII code  
  
    printf ( "code1 = %c\n" , code1);  
    printf ( "code2 = %c\n" , code2);  
}
```



```
code1 = A  
code2 = A
```


Tip: Korean How to express

How to express Hangul

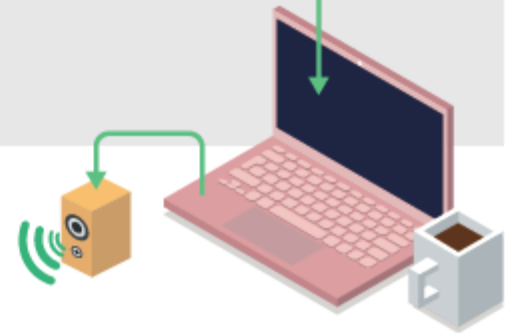
Hangul cannot be expressed in 8 bits. This is because there are more characters than English letters. There are two main ways to express Hangul on a computer. The first is to assign a code to each letter. For example, '가' is assigned the code 0xb0a1. The number of letters that can be expressed in Hangul is 11,172, so 8 bits ($2^8=256$) are not enough to assign codes to these letters, and 16 bits ($2^{16}=65,536$) are required. This is called a complete form. A representative code system is Unicode. Unicode is an industry standard designed to consistently express and handle all characters in the world on computers. It is established by the Unicode Consortium, and the current latest version is Unicode 10.0. This standard includes character sets, character encodings, character information databases, and algorithms for handling characters. Another method is to use the same 16 bits, but assign 5 bits to each of the initial consonant, medial vowel, and final consonant of the letter, and use the first bit as a symbol to distinguish between alphanumeric characters and Hangul. In other words, if the first bit is 1, it is Hangul, and if it is 0, it is an alphanumeric character. This method of expressing Hangul is called a combinational method.

Control characters

- Characters used for control purposes rather than printing purposes.
 - (Example) Line break character , tab character , ringtone character ,

```
char beep = 7;  
printf("%c", beep);
```

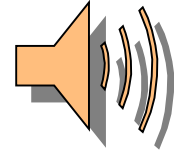
printf("%c", 7);



How to represent control characters

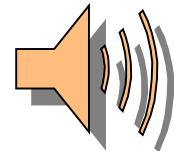
- Use ASCII code directly

```
char beep = 7;  
printf ("%c", beep);
```



- Using escape sequences

```
char beep = '\a';  
printf ("%c ", beep);
```



Escape Sequence

control character	name	meaning
<code>\0</code>	null character	
<code>\a</code>	warning(bell)	A "beep" warning sound occurs
<code>\b</code>	backspace	Moves the cursor one character back from its current position.
<code>\t</code>	horizontal tab	Moves the cursor position to the next tab position set on the current line.
<code>\n</code>	newline	Moves the cursor to the beginning of the next line.
<code>\v</code>	vertical tab	Move the cursor to the next set vertical tab position
<code>\f</code>	form feed	It is mainly used in printers to force the printer to turn to the next page.
<code>\r</code>	carriage return	Moves the cursor to the beginning of the current line.
<code>\"</code>	double quotation marks	The original double quotes themselves
<code>\'</code>	single quote	The original single quote itself
<code>\\</code>	backslash	The original backslash itself

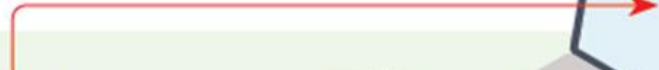
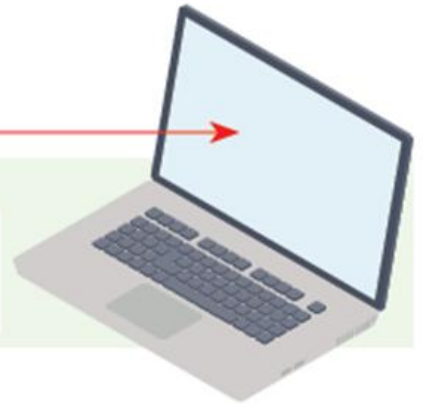
How to make a program beep ?

To make your program emit a beep using a special string, do the following:

```
char beep = '\a';  
printf("%c", beep);
```

```
printf("\a");
```

beep



Backslash \

- Backslash before characters with special functions
If you place \, the special meaning of the character is lost .

```
printf (" \" My own Hollywood \" UCC craze ");
```



```
"My Own Hollywood" UCC Craze
```

```
printf (" \\ is used to display control characters . ");
```



```
\ is used to indicate control characters .
```

Example

```
#include <stdio.h>
int main(void)
{
    int id, pass;

    printf ( " Please enter your ID and password as 4 digits :\n" );

    printf ( "id: ____\b\b\b\b " );
    scanf ( "%d" , &id);

    printf ( "pass: ____\b\b\b\b " );
    scanf ( "%d" , &pass);
    printf ( "\a The entered ID is \"%d\" and the password is \"%d\" ." , id, pass);

    return 0;
}
```

your ID and password using 4 digits :

id: 1234

pass: 5678


The entered ID is "1234" and the password is "5678" .

char type as integer

- The char type can be used to store 8- bit integers .

```
#include <stdio.h>

int main( void )
{
    char code = 'A' ;
    printf ( "%d %d %d \n" , code, code + 1, code + 2); // 65 66 67 is printed .
    printf ( "%c %c %c \n" , code, code + 1, code + 2); // ABC is printed .
    return 0;
}
```

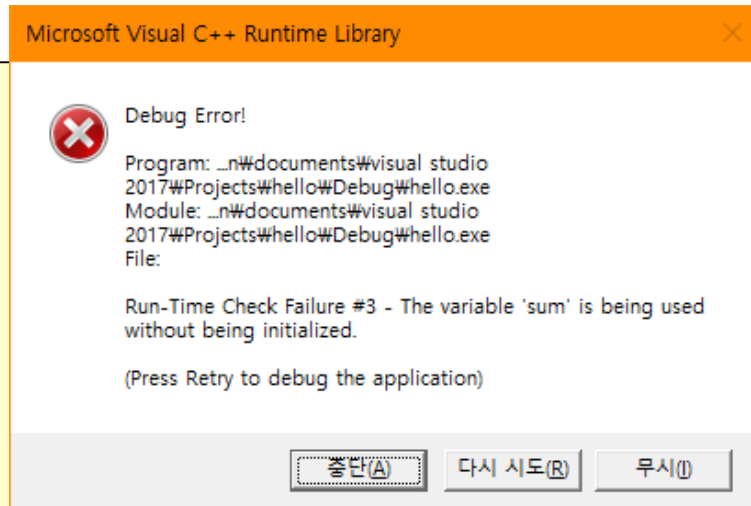


65 66 67
ABC

Lab: Variables Initial value

```
#include <stdio.h>
int main( void )
{
    int x, y, z, sum;

    printf (" Enter three integers (x, y, z): ");
    scanf ("%d %d %d", &x, &y, &z);
    sum += x;
    sum += y;
    sum += z;
    printf (" The sum of three integers is %d\n", sum);
    return 0;
}
```



What could be the problem ?

```
#include <stdio.h>
int main( void )
{
    int x, y, z, sum;

    sum = 0;
    printf (" Enter three integers (x, y, z): ");
    scanf ("%d %d %d", &x, &y, &z);
    sum += x;
    sum += y;
    sum += z;
    printf (" The sum of three integers is %d\n", sum);

    return 0;
}
```

Variables must be
initialized before use !

Enter 3 integers (x, y, z): 10 20 30
three integers is 60

Q & A

