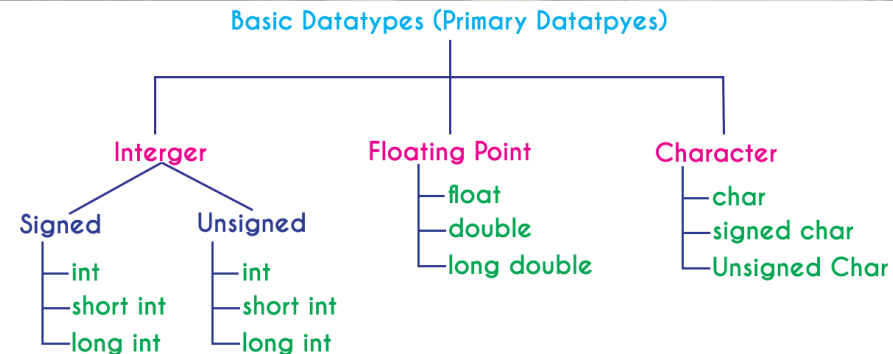


Lecture 7 - Basic Types

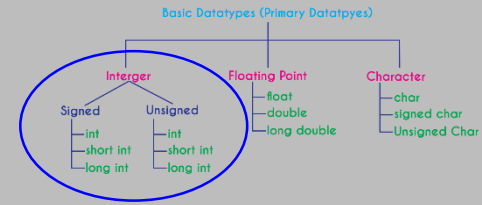
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Basic Types

- C's **basic** (built-in) **types**:
 - Integer types, including `long integers`, `short integers`, and `unsigned integers`
 - Floating types (`float`, `double`, and `long double`)
 - `char`
 - `_Bool` (**C99**)

Signed and Unsigned Integers



- The integer types, in turn, are divided into two categories: **signed** and **unsigned**.
- The **leftmost bit** of a **signed integer** (known as the **sign bit**) is **0** if the number is **positive or zero**, **1** if it's **negative**.
 - By **default**, integer variables are **signed** in C.
- An integer with **no sign bit** (the leftmost bit is considered part of the number's magnitude) should be declared as **unsigned**.
 - **Unsigned** numbers are primarily useful for **systems programming** and **low-level, machine-dependent** applications.

Long and Short Integers

- The `int` type is **usually 32 bits**, but may be **16 bits on older CPUs**.
- **Long** integers may have **more bits** than ordinary integers; **short** integers may have **fewer bits**.
- The specifiers `long` and `short`, as well as `signed` and `unsigned`, can be **combined with** `int` to form integer types.
- Only six combinations produce different types:

<code>short int</code>	<code>unsigned short int</code>
<code>int</code>	<code>unsigned int</code>
<code>long int</code>	<code>unsigned long int</code>
- The **order** of the specifiers **doesn't matter**. Also, the word `int` **can be dropped** (`long int` can be abbreviated to just `long`).

Range of Integer Values

- The **range of values** represented by each of the six integer types **varies from one machine to another**.
- However, the **C standard requires** that `short int`, `int`, and `long int` must **each cover a certain minimum range of values**.
- Also, `int` must not be shorter than `short int`, and `long int` must not be shorter than `int`.
- The `<limits.h>` header **defines macros** that represent the **smallest and largest values** of each integer type.

Range of Integer Values (cont.)

- Typical ranges of values for the integer types on a **16-bit machine**:

<i>Type</i>	<i>Smallest Value</i>	<i>Largest Value</i>	
short int	-32,768	32,767	16-bit
unsigned short int	0	65,535	
int	-32,768	32,767	16-bit
unsigned int	0	65,535	
long int	-2,147,483,648	2,147,483,647	32-bit
unsigned long int	0	4,294,967,295	

Range of Integer Values (cont.)

- Typical ranges on a 32-bit machine:

Type	Smallest Value	Largest Value	
short int	-32,768	32,767	16-bit
unsigned short int	0	65,535	
int	-2,147,483,648	2,147,483,647	32-bit
unsigned int	0	4,294,967,295	
long int	-2,147,483,648	2,147,483,647	32-bit
unsigned long int	0	4,294,967,295	

Range of Integer Values (cont.)

- Typical ranges on a 64-bit machine:

Type	Smallest Value	Largest Value	
short int	-32,768	32,767	16-bit
unsigned short int	0	65,535	
int	-2,147,483,648	2,147,483,647	32-bit
unsigned int	0	4,294,967,295	
long int	-2^{63}	$2^{63}-1$	64-bit
unsigned long int	0	$2^{64}-1$	

Integer Types in C99

- **C99** provides two additional standard integer types, `long long int` and `unsigned long long int`.
- Both `long long` types are required to be **at least 64 bits** wide.
- The range of `long long int` values is **typically** -2^{63} ($-9,223,372,036,854,775,808$) **to** $2^{63} - 1$ ($9,223,372,036,854,775,807$).
- The range of `unsigned long long int` values is **usually** 0 **to** $2^{64} - 1$ ($18,446,744,073,709,551,615$).

Integer Constants

- **Constants** are numbers that appear in the text of a program.
- C allows integer constants to be written in decimal (base 10), octal (base 8), or hexadecimal (base 16).

Integer Constants (cont.)

- **Decimal** constants contain digits between 0 and 9, but **must not begin with a zero**:

15 255 32767

- **Octal** constants contain only digits between 0 and 7, **and must begin with a zero**:

017 0377 077777

- **Hexadecimal** constants contain digits between 0 and 9 and letters between a and f, and **always begin with 0x**:

0xf 0xff 0x7fff

- The letters in a hexadecimal constant **may be either upper or lower case**:

0xff 0xFF 0xfF 0xFF 0Xff 0XfF 0XFF 0XFF

Integer Constants (cont.)

- To force the compiler to treat a constant as a **long integer**, just follow it with the letter **L** (or **l**):

15L 0377L 0x7fffL

- To indicate that a constant is **unsigned**, put the letter **U** (or **u**) after it:

15U 0377U 0x7fffU

- **L** and **U** may be used in **combination**:

0xffffffffUL

The **order** of the **L** and **U** **doesn't matter**, **nor** does **their case**.

Integer Constants in C99

- In **C99**, integer constants that end with either **LL** or **ll** (the **case of the two letters must match**) have type **long long int**.
- Adding the letter **U** (or **u**) before or after the **LL** or **ll** denotes a constant of type **unsigned long long int**.

Integer Overflow

- When **arithmetic operations** are performed on integers, it's possible that the **result** will **be too large to represent**. (we say that **overflow** has occurred)
- The **behavior** when integer overflow occurs **depends on** whether the operands were **signed** or **unsigned**.
 - When overflow occurs during an operation on **signed** integers, the program's **behavior is undefined**.
 - When overflow occurs during an operation on **unsigned** integers, **the result is defined**: we get **the correct answer modulo 2^n** , where n is the number of bits used to store the result.

Reading and Writing Integers

- Reading and writing **unsigned**, **short**, and **long** integers **requires new conversion specifiers**.
- When reading or writing an **unsigned integer**, **use** the letter **u**, **o**, or **x** instead of **d** in the conversion specification.

```
unsigned int u;
```

```
scanf("%u", &u); /* reads u in base 10 */
printf("%u", u); /* writes u in base 10 */
scanf("%o", &u); /* reads u in base 8 */
printf("%o", u); /* writes u in base 8 */
scanf("%x", &u); /* reads u in base 16 */
printf("%x", u); /* writes u in base 16 */
```

Reading and Writing Integers (cont.)

- When reading or writing a *short* integer, put the letter *h* in front of *d*, *o*, *u*, or *x*:

```
scanf ("%hd", &s) ;  
printf ("%hd", s) ;
```

- When reading or writing a *long* integer, put the letter *l* (“ell,” not “one”) in front of *d*, *o*, *u*, or *x*.

```
scanf ("%ld", &l) ;  
printf ("%ld", l) ;
```

- When reading or writing a *long long* integer (C99 only), put the letters *ll* in front of *d*, *o*, *u*, or *x*.

```
scanf ("%lld", &s) ;  
printf ("%lld", s) ;
```


Program: Summing a Series of Numbers (Revisited)

- The `sum.c` program (Lecture 6) sums a series of integers.
- **One problem** with this program is that **the sum** (or one of the input numbers) **might exceed the largest value allowed for an `int` variable**.
- Here's what might happen if the program is run on a machine whose integers are 16 bits long:

This program sums a series of integers.

Enter integers (0 to terminate): 10000 20000 30000 0

The sum is: -5536

- When **overflow** occurs with signed numbers, the outcome is undefined.
- The program **can be improved by using `long` variables**.

Program: Summing a Series of Numbers (Revisited) (cont.)

```
sum2.c
#include <stdio.h>

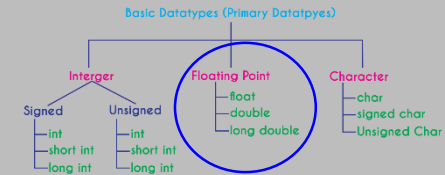
int main(void)
{
    long n, sum = 0;

    printf("This program sums a series of integers.\n");
    printf("Enter integers (0 to terminate): ");

    scanf("%ld", &n);
    while (n != 0) {
        sum += n;
        scanf("%ld", &n);
    }
    printf("The sum is: %ld\n", sum);

    return 0;
}
```

Floating Types



- C provides three ***floating types***: `float`, `double` and `long double`
- `float` is suitable when the amount of **precision isn't critical**.
- `double` provides **enough precision** for most programs.
- `long double` is **rarely used**.
- The C standard **doesn't state** how much **precision** the `float`, `double`, and `long double` types provide, since that depends on how numbers are stored.
- **Most modern computers follow** the specifications in **IEEE Standard 754** (also known as **IEC 60559**).

The IEEE Floating-Point Standard

- IEEE Standard 754 has **two primary formats** for floating-point numbers: **single precision (32 bits)** and **double precision (64 bits)**.
- Numbers are stored in a form of scientific notation, with each number having a **sign**, an **exponent**, and a **fraction**.
- In **single-precision** format, the **exponent** is **8 bits** long, while the **fraction** occupies **23 bits**. The **maximum value** is **approximately 3.40×10^{38}** , with a **precision** of **about 6 decimal digits**.

Characteristics of Floating Types

- Characteristics of `float` and `double` when implemented according to the **IEEE standard 754**:

<i>Type</i>	<i>Smallest Positive Value</i>	<i>Largest Value</i>	<i>Precision</i>
<code>float</code>	1.17549×10^{-38}	3.40282×10^{38}	6 digits
<code>double</code>	2.22507×10^{-308}	1.79769×10^{308}	15 digits

- On computers that **don't follow** the IEEE standard, this **table won't be valid**.
- In fact, on some machines, `float` may have the same set of values as `double`, or `double` may have the same values as `long double`.

Floating Types

- Macros that define the **characteristics of the floating types** can be found in the `<float.h>` header.
- In **C99**, the floating types are divided **into two categories**.
 - **Real floating types** (`float`, `double`, `long double`)
 - **Complex types** (`float _Complex`, `double _Complex`, `long double _Complex`)

Floating Constants

- Floating constants can be written in **a variety of ways**.

- Valid ways** of writing the number **57.0**:

57.0 57. 57.0e0 57E0 5.7e1 5.7e+1 .57e2 570.e-1

- A floating constant must contain a decimal point and/or an exponent; the exponent indicates the **power of 10** by which the number is to be scaled.
- If an exponent is present, it must be preceded by the letter **E** (or **e**). An **optional** **+** or **-** sign may appear after the **E** (or **e**).

Floating Constants (cont.)

- By **default**, floating constants are stored as **double-precision** numbers.
- To **indicate that only single precision is desired**, **put** the letter **F** (or **f**) at the end of the constant (for example, **57.0F**).
- To **indicate that a constant should be stored in long double** format, **put** the letter **L** (or **l**) at the end (**57.0L**).

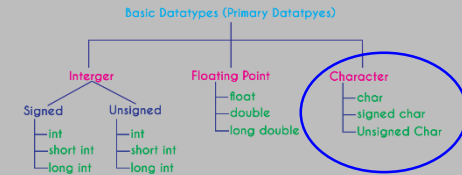
Reading and Writing Floating-Point Numbers

- The conversion specifications `%e`, `%f`, and `%g` are used for reading and writing **single-precision** floating-point numbers.
- When **reading a value** of type `double`, **put** the letter `l` in front of `e`, `f`, or `g`:

```
double d;  
scanf("%lf", &d);
```

- *Note:* Use `l` only in a `scanf` format string, not a `printf` string.
- In a `printf` format string, the `e`, `f`, and `g` conversions can be used to write either `float` or `double` values.
- When reading or writing a value of type `long double`, **put** the letter `L` in front of `e`, `f`, or `g`.

Character Types



- The only remaining basic type is `char`, the **character type**.
- The values of type `char` can **vary from one computer to another**, because different machines may have different underlying character sets.
- Today's most popular character set is **ASCII** (American Standard Code for Information Interchange), a **7-bit code** capable of representing **128 characters**.
- ASCII is **often extended** to a **256-character** code known as **Latin-1** that provides the characters necessary for **Western European** and many **African** languages.

Character Assignments

- A variable of type `char` can be assigned any single character:

```
char ch;
```

```
ch = 'a';    /* lower-case a */
```

```
ch = 'A';    /* upper-case A */
```

```
ch = '0';    /* zero */
```

```
ch = ' ';    /* space */
```

- Notice that **character constants** are **enclosed in single quotes**, **not double quotes**.

Operations on Characters

- Working with characters in C is simple, because of one fact: *C treats characters as small integers.*
- In ASCII, character codes range from 00000000 to 11111111, which *we can think of as the integers from 0 to 127.*
- The character *'a'* has the value *97*, *'A'* has the value *65*, *'0'* has the value *48*, and *' '* has the value *32*.

Operations on Characters

- **Character constants** actually have `int` type **rather than** `char` type.
- When a character appears **in a computation**, **C uses its integer value**.
- Consider the following examples, which assume the ASCII character set:

```
char ch;  
int i;
```

```
i = 'a';           /* i is now 97      */  
ch = 65;           /* ch is now 'A'    */  
ch = ch + 1;       /* ch is now 'B'    */  
ch++;              /* ch is now 'C'    */
```

Operations on Characters (cont.)

- Characters **can be compared**, just as numbers can.
- An `if` statement that **converts a lower-case letter to upper case**:

```
if ( 'a' <= ch && ch <= 'z' )  
    ch = ch - 'a' + 'A';
```

- **Comparisons** such as `'a' <= ch` are **done using the integer values of the characters** involved.
- These values depend on the character set in use, so **programs that use `<`, `<=`, `>`, and `>=` to compare characters may not be portable**.

Operations on Characters (cont.)

- The fact that characters have the same properties as numbers **has advantages**.
- For example, it is **easy to write a for statement** whose control variable steps through all the upper-case letters:

```
for (ch = 'A'; ch <= 'Z'; ch++) ...
```
- **Disadvantages** of treating characters as numbers:
 - **Can lead to errors** that won't be caught by the compiler.
 - **Allows meaningless expressions** such as `'a' * 'b' / 'c'`.
 - **Can hamper portability**, since programs may rely on assumptions about the underlying character set.

Signed and Unsigned Characters

- The `char` type—like the integer types—exists in both signed and unsigned versions.
- **Signed** characters normally have values **between -128 and 127**. **Unsigned** characters have values **between 0 and 255**.
- Some compilers treat `char` as a signed type, while others treat it as an unsigned type. **Most of the time, it doesn't matter.**
- C allows the use of the words `signed` and `unsigned` to modify `char`:

```
signed char sch;  
unsigned char uch;
```


Escape Sequences

- A **character constant** is usually **one character enclosed in single quotes** (ex. 'a').
- However, certain **special characters**—including the new-line character—can't be written in this way, because they're **invisible** (nonprinting) **or** because they **can't be entered from the keyboard**.
- **Escape sequences** (enclosed in **single quotes**) provide a way to represent these characters.
- There are two kinds of escape sequences: **character escapes** and **numeric escapes**.
- Escape sequences **can be embedded in strings** as well.

Character Escapes

- Character escapes are **handy, but they don't exist for all nonprinting ASCII characters.**
- **Numeric escapes**, which can represent any character, are the solution to this problem.
- A numeric escape for a particular character uses the character's **octal** or **hexadecimal** value.

<i>Name</i>	Char	Oct	Hex	Dec
Alert (bell)	\a	\7	\x07	7
Backspace	\b	\10	\x08	8
Form feed	\f	\14	\x0c	12
New line	\n	\12	\x0a	10
Carriage return	\r	\15	\x0d	13
Horizontal tab	\t	\11	\x09	9
Vertical tab	\v	\13	\x0b	11
Backslash	\\	\134	\x27	92
Question mark	\?	\77	\x22	63
Single quote	\'	\47	\x5c	39
Double quote	\"	\42	\x3f	34

Rarely used

Numeric Escapes

- An **octal escape sequence** consists of the `\` character followed by an **octal** number with **at most three digits**, such as `\33` or `\033` (with normally **maximum** value `\377`).
- A **hexadecimal escape sequence** consists of `\x` followed by a **hexadecimal** number, such as `\x1b` or `\x1B` (with normally **maximum** value `\xFF`)..
- The **x** must be in lower case, but the **hex digits** can be upper or lower case.
- Escape sequences tend to get a bit cryptic, so it's often a **good idea** to use `#define` to give them names:

```
#define ESC '\33'
```

Character-Handling Functions

- Calling C's `toupper` library function is a **fast** and **portable** way to convert case:

```
ch = toupper(ch);
```

- `toupper` returns the **upper-case version** of its argument.
- Programs that call `toupper` need to have the following `#include` directive at the top:

```
#include <ctype.h>
```

- The C library provides many other useful character-handling functions.

Reading and Writing Characters Using `scanf` and `printf`

- The `%c` conversion specification allows `scanf` and `printf` to read and write single characters:

```
char ch;
```

```
scanf("%c", &ch); /* reads one character */  
printf("%c", ch); /* writes one character */
```

- `scanf` **doesn't skip white-space** characters.
- To force `scanf` **to skip white space** before reading a character, **put a space** in its format string just **before %c**:

```
scanf(" %c", &ch);
```

Reading and Writing Characters

Using `scanf` and `printf` (cont.)

- Since `scanf` doesn't normally skip white space, **it's easy to detect the end of an input line**: check to see if the character just read is the new-line character.
- A loop that reads and **ignores all remaining characters in the current input line**:

```
do {  
    scanf("%c", &ch);  
} while (ch != '\n');
```
- When `scanf` is called the next time, it will read the first character on the next input line.

Reading and Writing Characters Using `getchar` and `putchar`

- For **single-character** input and output, `getchar` and `putchar` are an alternative to `scanf` and `printf`.
- `putchar` **writes a character**:
`putchar(ch);`
- Each time `getchar` is called, it **reads one character**, which it returns:
`ch = getchar();`
- `getchar` **returns an int** value rather than a `char` value, so `ch` will often have type `int`.
- Like `scanf`, `getchar` **doesn't skip white-space** characters as it reads.

Reading and Writing Characters Using `getchar` and `putchar` (cont.)

- Using `getchar` and `putchar` (rather than `scanf` and `printf`) saves execution time.
 - `getchar` and `putchar` are much simpler than `scanf` and `printf`, which are designed to read and write many kinds of data in a variety of formats.
 - They are usually implemented as macros for additional speed.
- `getchar` has another advantage. Because it returns the character that it reads, `getchar` lends itself to various C idioms.

Reading and Writing Characters Using `getchar` and `putchar` (cont.)

- Consider the `scanf` loop that we used to skip the rest of an input line. We can **rewriting this loop using `getchar`** gives us the following:

```
do {  
    scanf("%c", &ch);  
} while (ch != '\n');
```

```
do {  
    ch = getchar();  
} while (ch != '\n');
```

```
while ((ch = getchar()) != '\n')  
    ;
```

```
while (getchar() != '\n')  
    ;
```

(when the `ch` variable isn't even needed)

Reading and Writing Characters

Using `getchar` and `putchar` (cont.)

- `getchar` is useful in loops that **skip characters** as well as loops that **search for characters**.
- A statement that uses `getchar` to **skip** an indefinite number of **blank characters**:

```
while ((ch = getchar()) == ' ')  
    ;
```

- When the loop terminates, `ch` will contain the first nonblank character that `getchar` encountered.

Reading and Writing Characters Using `getchar` and `putchar` (cont.)

- Be careful when **mixing** `getchar` and `scanf`.
- `scanf` has a tendency to leave behind characters that it has “peeked” at but not read, including the new-line character:

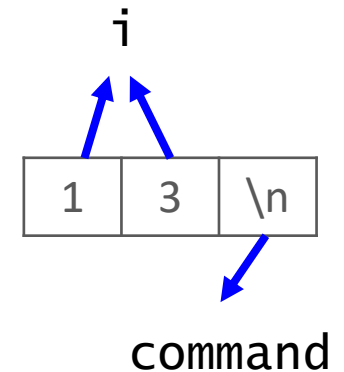
```
printf("Enter an integer: ");  
scanf("%d", &i);  
printf("Enter a command: ");  
command = getchar();
```

`scanf` will leave behind any characters that weren't consumed during the reading of `i`, including (but not limited to) the new-line character.

- `getchar` will fetch the first leftover character.

Reading and Writing Characters Using `getchar` and `putchar` (cont.)

```
1 #include <stdio.h>
2
3 int main()
4 {
5     int i, command;
6     printf("Enter an integer: ");
7     scanf("%d", &i);
8
9     printf("Enter a command: ");
10    command = getchar();
11
12    printf("i is %d\n", i);
13    printf("command is %x\n", command);
14
15    return 0;
16 }
```



```
Enter an integer: 13
Enter a command: i is 13
command is  a
```

Program: Determining the Length of a Message

- The `length.c` program displays the length of a message entered by the user:

```
Enter a message: Brevity is the soul of wit.  
Your message was 27 character(s) long.
```

- The length **includes** spaces and punctuation, but **not** the new-line character at the end of the message.
- We could use either `scanf` or `getchar` to read characters; **most C programmers would choose** `getchar`.
- `length2.c` is a shorter program that eliminates the variable used to store the character read by `getchar`.

Program: Determining the Length of a Message (cont.)

length.c

```
#include <stdio.h>
int main(void)
{
    char ch;
    int len = 0;

    printf("Enter a message: ");
    ch = getchar();
    while (ch != '\n') {
        len++;
        ch = getchar();
    }
    printf("Your message was %d
character(s) long.\n", len);
    return 0;
}
```

length2.c

```
#include <stdio.h>

int main(void)
{
    int len = 0;

    printf("Enter a message: ");
    while (getchar() != '\n')
        len++;
    printf("Your message was %d
character(s) long.\n", len);

    return 0;
}
```



Enter a message: Hello World

Your message was 11 character(s) long.

Type Conversion

- For a computer to perform an **arithmetic operation**, the **operands** must usually be of **the same size** (the same number of bits) and be **stored in the same way**.
- **When** operands of different **types are mixed** in expressions, the **C compiler** may have to **generate instructions that change the types of some operands** so that hardware will be able to evaluate the expression.
 - If we add a **16-bit short** and a **32-bit int**, the compiler will arrange for the **short** value to be **converted to 32 bits**.
 - If we add an **int** and a **float**, the compiler will arrange for the **int** to be **converted to float** format.

Type Conversion (cont.)

- Because the **compiler handles these conversions automatically**, without the programmer's involvement, they're known as ***implicit conversions***.
- C also allows the **programmer** to **perform *explicit conversions***, using the **cast operator**.
- The rules for performing **implicit conversions are somewhat complex**, primarily because C has so many different arithmetic types.

Type Conversion (cont.)

- Implicit conversions are performed:
 - When the **operands** in an **arithmetic or logical expression** **don't have the same type**. (C performs what are known as the ***usual arithmetic conversions***.)
 - When the type of the expression on the **right side** of an **assignment** **doesn't match** the type of the variable on the **left side**.
 - When the **type of an argument** in a **function call** **doesn't match** the type of the **corresponding parameter**.
 - When the **type of the expression** in a **return statement** **doesn't match** the function's **return type**.

Lecture 9

The Usual Arithmetic Conversions

- The usual arithmetic conversions are applied to the operands of **most binary operators**.
- If `f` has type `float` and `i` has type `int`, in the expression `f + i`, clearly it's **safer to convert `i` to type `float`** (matching `f`'s type) rather than convert `f` to type `int` (matching `i`'s type).
- When an **integer is converted to `float`**, the worst that can happen is a **minor loss of precision**.
- **Converting a floating-point number to `int`**, on the other hand, causes the **fractional part of the number to be lost**. Worse still, the result will be **meaningless** if the **original number is larger than the largest possible integer** or **smaller than the smallest integer**.

3.8 -> 3

Program: Converting integer to float

```
1 #include <stdio.h>
2 int main()
3 {
4     int x = 0x1fffffff;
5     float y;
6     y = x;
7     printf("x = %d\n", x);
8     printf("y = %f\n", y);
9
10    return 0;
11 }
```

<pre>x = 33554431 y = 33554432.000000</pre>

The Usual Arithmetic Conversions (cont.)

- Strategy behind the usual arithmetic conversions: **convert operands to the “narrowest” type that will safely accommodate both values.**
- Operand types can often be made to match by converting the operand of the narrower type to the type of the other operand (this act is known as **promotion**).
- Common promotions include the **integral promotions**, which **convert a character or short integer to type `int` (or to `unsigned int` in some cases).**
- The rules for performing the usual arithmetic conversions can be divided into two cases:
 - The type of **either** operand is a **floating** type.
 - **Neither** operand type is a **floating** type.

The Usual Arithmetic Conversions (cont.)

- **The type of *either* operand is a floating type.**
 - If one operand has type `long double`, then convert the other operand to type `long double`.
 - Otherwise, if one operand has type `double`, convert the other operand to type `double`.
 - Otherwise, if one operand has type `float`, convert the other operand to type `float`.
- Example: If one operand has type `long int` and the other has type `double`, the `long int` operand is converted to `double`.

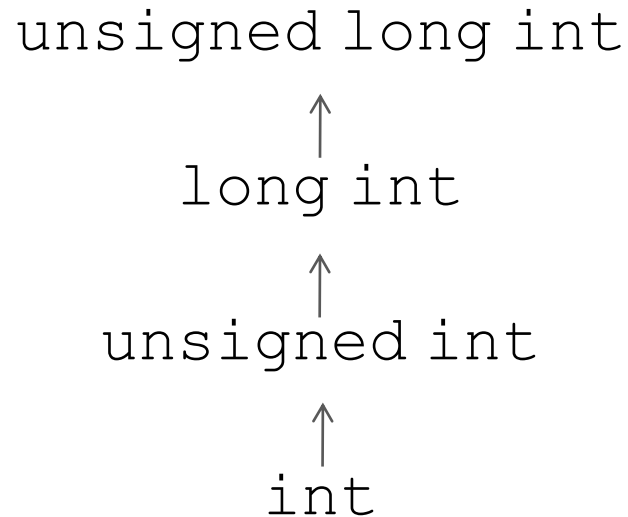
`long int + double`



`double + double`

The Usual Arithmetic Conversions (cont.)

- ***Neither operand type is a floating type.*** First perform integral promotion on both operands.
- Then use the following diagram to promote the operand whose type is narrower:



The Usual Arithmetic Conversions (cont.)

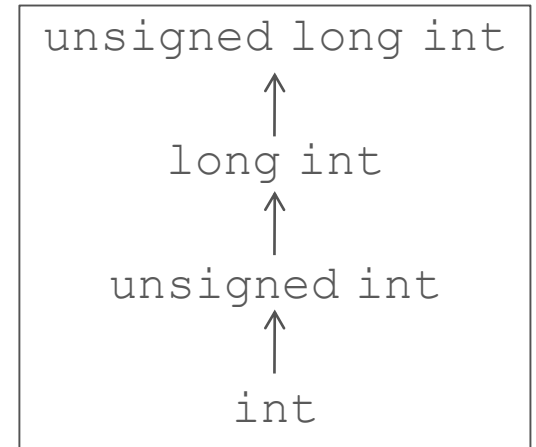
- When a **signed** operand is **combined with** an **unsigned** operand, the signed operand is converted to an **unsigned** value.
- This rule can cause obscure programming errors.
- **It's best to use unsigned integers as little as possible and, especially, never mix them with signed integers.**

The Usual Arithmetic Conversions (cont.)

- Example of the usual arithmetic conversions:

```
char c;  
short int s;  
int i;  
unsigned int u;  
long int l;  
unsigned long int ul;  
float f;  
double d;  
long double ld;
```

```
i = i + c;      /* c is converted to int */  
i = i + s;      /* s is converted to int */  
u = u + i;      /* i is converted to unsigned int */  
l = l + u;      /* u is converted to long int */  
ul = ul + l;    /* l is converted to unsigned long int */  
f = f + ul;     /* ul is converted to float */  
d = d + f;      /* f is converted to double */  
ld = ld + d;    /* d is converted to long double */
```



Conversion During Assignment

- The **usual arithmetic conversions** don't apply to assignment.
- Instead, the **expression on the right side** of the assignment is **converted to the type of the variable on the left side**:

```
char c;  
int i;  
float f;  
double d;
```

```
i = c;    /* c is converted to int */  
f = i;    /* i is converted to float */  
d = f;    /* f is converted to double */
```

Conversion During Assignment (cont.)

- Assigning a **floating-point number to an integer** variable **drops the fractional part** of the number:

```
int i;
```

```
i = 842.97;      /* i is now 842 */
```

```
i = -842.97;     /* i is now -842 */
```

- Assigning a value to a variable of a **narrower type** will give a **meaningless result** (or worse) if the value is outside the range of the variable's type:

```
c = 10000;      /*** WRONG ***/
```

```
i = 1.0e20;     /*** WRONG ***/
```

```
f = 1.0e100;    /*** WRONG ***/
```

> 255

> 2147483647

> 3.40282×10^{38}

Conversion During Assignment (cont.)

- It's a **good idea to append the `f` suffix** to a floating-point constant if it will be assigned to a `float` variable:

```
f = 3.14159f;
```

- Without the suffix**, the constant **`3.14159`** would have type `double`, possibly causing a warning message.

Casting

- Although C's implicit conversions are convenient, **we sometimes need a greater degree of control over type conversion.**
- For this reason, C provides **casts**.
- A cast expression has the form
(type-name) expression

type-name specifies the type to which the expression should be converted.

Casting (cont.)

- Using a cast expression **to compute the fractional part** of a float value:

```
float f, frac_part;
```

```
frac_part = f - (int) f;
```

- The difference between `f` and `(int) f` is the fractional part of `f`, which was dropped during the cast.
- Cast expressions **enable us to document type conversions** that would take place anyway:

```
i = (int) f; /* f is converted to int */
```

Casting (cont.)

- Cast expressions also let us **force the compiler to perform conversions**.

- Example:

```
float quotient;
```

```
int dividend, divisor;
```

```
quotient = dividend / divisor;
```

- **To avoid truncation during division**, we need to **cast one of the operands**:

```
quotient = (float) dividend / divisor;
```

- **Casting dividend to float causes the compiler to convert divisor to float also.**

Casting (cont.)

- C regards (*type-name*) as a unary operator.

- Unary operators have higher precedence than binary operators, so the compiler interprets

`(float) dividend / divisor`

as

`((float) dividend) / divisor`

- Other ways to accomplish the same effect:

`quotient = dividend / (float) divisor;`

`quotient = (float) dividend / (float) divisor;`

Casting

- Casts are sometimes necessary **to avoid overflow**:

```
long i;  
int j = 1000;  
  
i = j * j;    /* overflow may occur */
```

- Using a cast avoids the problem:

```
i = (long) j * j;
```

- The statement

```
i = (long) (j * j);    /**** WRONG ****/
```

wouldn't work, since the overflow would already have occurred by the time of the cast.

Type Definitions

- The `#define directive` can be used to create a “Boolean type” macro:

```
#define BOOL int
```

- There’s **a better way** using a feature known as a ***type definition***:

```
typedef int Bool;
```

- `Bool` can now be used in **the same way as the built-in type names**.

- Example:

```
Bool flag;    /* same as int flag; */
```

Advantages of Type Definitions

- Type definitions can **make a program more understandable**.
- If the variables `cash_in` and `cash_out` will be used to store dollar amounts, declaring `Dollars` as

```
typedef float Dollars;
```

and then writing

```
Dollars cash_in, cash_out;
```

is more informative than just writing

```
float cash_in, cash_out;
```

Advantages of Type Definitions (cont.)

- Type definitions can also **make a program easier to modify**.
- **To redefine Dollars as double, only the type definition need be changed:**

```
typedef double Dollars;
```

- **Without the type definition, we would need to locate all float variables that store dollar amounts and change their declarations.**

Type Definitions and Portability

- Type definitions are an important tool for writing portable programs.
- One of the problems with moving a program from one computer to another is that types may have different ranges on different machines.
- If `i` is an `int` variable, an assignment like
`i = 100000;`
is fine on a machine with 32-bit integers, but will fail on a machine with 16-bit integers.

Type Definitions and Portability (cont.)

- For greater portability, consider using `typedef` to define new names for integer types.
- Suppose that we're writing a program that needs variables capable of storing product quantities in the range 0–50,000.
- We could use `long` variables for this purpose, but we'd rather use `int` variables, since arithmetic on `int` values may be faster than operations on `long` values. Also, `int` variables may take up less space.

Type Definitions and Portability (cont.)

- Instead of using the `int` type to declare quantity variables, **we can define our own “quantity” type**:

```
typedef int Quantity;
```

and use this type to declare variables:

```
Quantity q;
```

- **When we transport the program to a machine with shorter integers**, we'll change the type definition:

```
typedef long Quantity;
```

- Note that changing the definition of `Quantity` may affect the way `Quantity` variables are used.

Type Definitions and Portability (cont.)

- The **C library** itself **uses typedef to create names for types** that can vary from one C implementation to another; these types often have names that **end with _t**.
- Typical definitions of these types:

```
typedef long int ptrdiff_t;  
typedef unsigned long int size_t;  
typedef int wchar_t;
```
- In **C99**, the `<stdint.h>` header uses typedef to **define names for integer types with a particular number of bits**.

`ex. int32_t;`

The `sizeof` Operator

- The value of the expression

`sizeof (type-name)`

is an **unsigned integer** representing the **number of bytes required** to store a value belonging to *type-name*.

- `sizeof(char)` is **always 1**, but the sizes of the **other types may vary**.
- On a **32-bit machine**, `sizeof(int)` is **normally 4**.

The `sizeof` Operator (cont.)

- The `sizeof` operator can also be applied to **constants**, **variables**, and **expressions** in general.
 - If `i` and `j` are `int` variables, then `sizeof(i)` is **4** on a **32-bit machine**, as is `sizeof(i + j)`.
- When applied to an **expression**—as **opposed to a type**—`sizeof` **doesn't require parentheses**.
 - We could write `sizeof i` instead of `sizeof(i)`.
- Parentheses **may be needed** anyway **because of operator precedence**.
 - The compiler interprets `sizeof i + j` as `(sizeof i) + j`, because `sizeof` takes precedence over binary `+`.

The `sizeof` Operator (cont.)

- Printing a `sizeof` value requires care, because the type of a `sizeof` expression is an implementation-defined type named `size_t`.
- In C89, it's best to convert the value of the expression to a known type before printing it:

```
printf("Size of int: %lu\n",  
      (unsigned long) sizeof(int));
```

- The `printf` function in C99 can display a `size_t` value directly if the letter `z` is included in the conversion specification:

```
printf("Size of int: %zu\n", sizeof(int));
```

A Quick Review to This Lecture

- Integer types: (all can be signed or unsigned)
`short int / int / long int / long long int`
- Floating types: (usually IEEE Standard 754)
`float / double / long double`
- Complex types (C99):
`float _Complex / double _Complex / long double _Complex`
- Character types:
`char / signed char / unsigned char`
- Boolean type (C99): (unsigned, 0 or 1)
`_Bool`

A Quick Review to This Lecture (cont.)

- Types of integer constants

L or l for long int (ex. 15L)

U or u for unsigned int (ex. 15U 15uL)

LL or ll for long long int (ex. 15LL 15ULL)

- Different bases for integer

begin with non-zero: decimal (ex. 19)

begin with zero: octal (ex. 017)

begin with 0x or 0X: hexadecimal (ex. 0xff 0xFF)

- Integer Overflow

signed integer: undefined behavior

unsigned integer: correct answer modulo 2^n (n: number of bits)

A Quick Review to This Lecture (cont.)

- Reading and writing integers

`%h` for `short`

`%l` for `long`

`%ll` for `long long`

`%d` for `signed int`

`%u`, `%o`, `%x` for `unsigned int` (base 10, 8, 16)

(ex. `printf("%ld", var);` //signed long (base 10))

- Floating constants (must contain a decimal point and/or an exponent)

57.0 can be expressed as

57.0 57. 57.0e0 57E0 5.7e1 5.7e+1 .57e2 570.e-1

(e for **power of 10**)

A Quick Review to This Lecture (cont.)

- Types of floating constants
 - F or f for float (ex. 57.0F)
 - (default) for double (ex. 57.0)
 - L or l for long double (ex. 57.0L 57.0l)
- Reading and writing floating-point numbers
 - scanf
 - %e, %f, %g for float
 - %le, %lf, %lg for double
 - %Le, %Lf, %Lg for long double
 - printf
 - %e, %f, %g for float or double
 - %Le, %Lf, %Lg for long double

A Quick Review to This Lecture (cont.)

- Character assignment

```
char ch = 'a' // single quote, not double quote
```

- C treats characters as **small integers** (mostly **ASCII** / **Latin-1** codes)

- Character constants have **int** type rather than `char` type

- Converting a lower-case letter to upper case

```
1. if ('a' <= ch && ch <= 'z') // ASCII assumed
    ch = ch - 'a' + 'A';
```

```
2. #include <ctype.h>
```

```
    ch = toupper(ch); // character set independent
```

- C allows the use of the words **signed** and **unsigned** to modify `char`:

```
signed char sch;
```

```
unsigned char uch;
```

A Quick Review to This Lecture (cont.)

- Character Escapes
- Using macro to define non-printable characters

```
#define ESC '\33'
```

<i>Name</i>	Char	Oct	Hex	Dec
Alert (bell)	\a	\7	\x07	7
Backspace	\b	\10	\x08	8
Form feed	\f	\14	\x0c	12
New line	\n	\12	\x0a	10
Carriage return	\r	\15	\x0d	13
Horizontal tab	\t	\11	\x09	9
Vertical tab	\v	\13	\x0b	11
Backslash	\\	\134	\x27	92
Question mark	\?	\77	\x22	63
Single quote	\'	\47	\x5c	39
Double quote	\"	\42	\x3f	34

Rarely used

A Quick Review to This Lecture (cont.)

- Reading and writing characters

1. `printf()` and `scanf()`: using `%c`

2. `putchar(ch);` // faster

`ch = getchar();` // return int, faster

- `scanf` and `getchar` **do not skip white-space** characters.

- To force `scanf` to skip white space before reading a character:

```
scanf(" %c", &ch);
```

↑
space

- **Be careful** when **mixing** `getchar` and `scanf`. `scanf` leaves behind characters that it has “peeked” at but not read,

A Quick Review to This Lecture (cont.)

- Ignoring all remaining characters in the current input line:

```
do {  
    scanf("%c", &ch);  
} while (ch != '\n');
```

```
do {  
    ch = getchar();  
} while (ch != '\n');
```

```
while ((ch = getchar()) != '\n')  
    ;
```

```
while (getchar() != '\n')  
    ;
```

(when the `ch` variable isn't even needed)

- Using `getchar` to skip an indefinite number of blank characters:

```
while ((ch = getchar()) == ' ')  
    ;
```

A Quick Review to This Lecture (cont.)

- Implicit type conversion
usual arithmetic conversion or assignment conversion
- Usual arithmetic conversion
 - The type of **either** operand is a **floating** type.
(other type) -> float -> double -> long double
 - **Neither** operand type is a **floating** type.
Integral promotion:
int -> unsigned int -> long int -> unsigned long int
- Assignment conversion
Right side is converted to left side

A Quick Review to This Lecture (cont.)

- Explicit type conversion (using cast operator)
`(type-name) expression`
- Computing the fractional part of a float value:
`float f, frac_part;
frac_part = f - (int) f;`
- To avoid truncation during division, we need to cast one operand:
`float quotient;
int dividend, divisor;
quotient = (float) dividend / divisor;`
- Casts are sometimes necessary **to avoid overflow**:
`long i;
int j = 1000;
i = (long) j * j;`

A Quick Review to This Lecture (cont.)

- Type definition

- 1. `#define BOOL int`

- 2. `typedef int Bool; // better`

- `<stdint.h>` header defines integer types with particular sizes

- `int32_t i;`

- `sizeof` operator **returns required bytes** (`size_t`) to store a value

- `sizeof (type-name)`

- `sizeof (expression)` or `sizeof expression`

- Print returned value of `sizeof`

- `printf("Size of int: %lu\n",`

- `(unsigned long) sizeof(int)); // C89`

- `printf("Size of int: %zu\n", sizeof(int)); // C99`