Chapter Two: Fundamental Data Types

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Chapter Goals

- To be able to define and initialize variables and constants
- To understand the properties and limitations of integer and floating-point numbers
- To write arithmetic expressions and assignment statements in C++
- To appreciate the importance of comments and good code layout
- To create programs that read and process input, and display the results
- To process strings, using the standard C++ **`string`** type

Variables

- A variable
  - is used to store information: the contents of the variable:
    - can contain one piece of information at a time.
  - has an identifier: the name of the variable

    The programmer picks a good name
    - A good name describes the contents of the variable or what the variable will be used for

Variables

Parking garages store cars.

Variables

Each parking space is identified
– like a variable's identifier

A each parking space in a garage "contains" a car
– like a variable's current contents.

Variables

and
each space can contain only *one* car

and
only cars, not buses or trucks

Variable Definitions

- When creating variables, the programmer specifies the type of information to be stored.
  - (more on types later)
- Unlike a parking space, a variable is often given an initial value.
  - *Initialization* is putting a value into a variable when the variable is created.
  - Initialization is not required.

Variable Definitions

The following statement defines a variable.

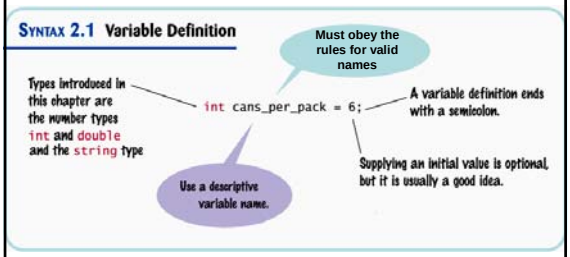
`cans_per_pack` is the variable's name.

```
int cans_per_pack = 6;
```

`int` indicates that the variable `cans_per_pack` will be used to hold integers.

`= 6` indicates that the variable `cans_per_pack` will initially contain the value 6.

Variable Definitions



Variable Definitions

Table 1 Variable Definitions in C++

Variable Name	Comment
`int cans = 6;`	Defines an integer variable and initializes it with 6.
`int total = cans + bottles;`	The initial value need not be a constant. (Of course, cans and bottles must have been previously defined.)
`int bottles = "10";`	**Error:** You cannot initialize a number with a string.
`int bottles;`	Defines an integer variable without initializing it. This can be a cause for errors—see Common Error 2.2 on page 37.
`int cans, bottles;`	Defines two integer variables in a single statement. In this book, we will define each variable in a separate statement.
`bottles = 1;`	**Caution:** The type is missing. This statement is not a definition but an assignment of a new value to an existing variable—see Section 2.1.4 on page 34.

Number Types

A number written by a programmer is called a *number literal*.

There are rules for writing literal values:

Number Types

Number	Type	Comment
6	int	An integer has no fractional part.
-6	int	Integers can be negative.
0	int	Zero is an integer.
0.5	double	A number with a fractional part has type double.
1.0	double	An integer with a fractional part .0 has type double.
1E6	double	A number in exponential notation: 1×10^6 or 1000000. Numbers in exponential notation always have type double.
2.96E-2	double	Negative exponent: $2.96 \times 10^{-2} = 2.96 / 100 = 0.0296$
100,000		**Error:** Do not use a comma as a decimal separator.
3 1/2		**Error:** Do not use fractions; use decimal notation: 3.5

Variable Names

- When you define a variable, you should pick a name that explains its purpose.
- For example, it is better to use a descriptive name, such as **`can_volume`**, than a terse name, such as **`cv`**.

Variable Names

In C++, there are a few simple rules for variable names:

Variable Names

1. Variable names must start with a letter or the underscore (_) character, and the remaining characters must be letters numbers, or underscores.
2. You cannot use other symbols such as $ or %. Spaces are not permitted inside names; you can use an underscore instead, as in **`can_volume`**.
3. Variable names are *case-sensitive*, that is, **`can_volume`** and **`can_Volume`** are different names.
   For that reason, it is a good idea to use only lowercase letters in variable names.
4. You cannot use *reserved words* such as **`double`** or **`return`** as names; these words are reserved exclusively for their special C++ meanings.

Variable Names

Table 3 Variable Names in C++

Variable Name	Comment
`can_volume1`	Variable names consist of letters, numbers, and the underscore character.
`x`	In mathematics, you use short variable names such as *x* or *y*. This is legal in C++, but not very common, because it can make programs harder to understand (see Programming Tip 2.1 on page 38).
⚠ `Can_volume`	**Caution:** Variable names are case-sensitive. This variable name is different from `can_volume`.
⊘ `6pack`	**Error:** Variable names cannot start with a number.
⊘ `can volume`	**Error:** Variable names cannot contain spaces.
⊘ `double`	**Error:** You cannot use a reserved word as a variable name.
⊘ `ltr/fl.oz`	**Error:** You cannot use symbols such as / or .

The Assignment Statement

- The contents in variables can "vary" over time (hence the name!).
- Variables can be changed by
  - assigning to them
    - The assignment statement
  - using the increment or decrement operator
  - inputting into them
    - The input statement

The Assignment Statement

- An *assignment statement*

  stores a new value in a variable,
  replacing the previously stored value.

The Assignment Statement

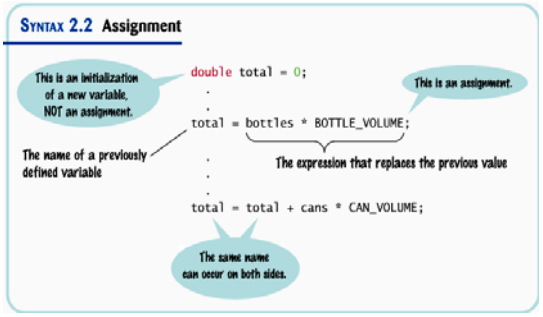
```
cans_per_pack = 8;
```

This assignment statement changes the value stored in **cans_per_pack** to be 8.

The previous value is replaced.

The Assignment Statement

SYNTAX 2.2 Assignment



The Assignment Statement

- There is an important difference between a variable definition and an assignment statement:

```
int cans_per_pack = 6; // Variable definition
...
cans_per_pack = 8; // Assignment statement
```

- The first statement is the *definition* of **cans_per_pack**.
- The second statement is an *assignment statement.* An *existing* variable's contents are replaced.

The Assignment Statement

- The = in an assignment does ***not*** mean the left hand side is equal to the right hand side as it does in math.
- = is an instruction to do something:
  copy the value of the expression on the right ***into*** the variable on the left.
- Consider what it would mean, mathematically, to state:

```
counter = counter + 2;
```

counter *EQUALS* counter + 1 ?

The Assignment Statement

```
counter = 11; // set counter to 11
counter = counter + 2; // increment
```


The Assignment Statement

```
counter = 11; // set counter to 11
counter = counter + 2; // increment
```

1. Look up what is currently in counter (11)

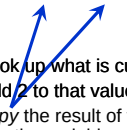
The Assignment Statement

```
counter = 11; // set counter to 11
counter = counter + 2; // increment
```

1. Look up what is currently in counter (11)
2. Add 2 to that value (13)

The Assignment Statement

```
counter = 11; // set counter to 11
counter = counter + 2; // increment
```



1. Look up what is currently in counter (11)
2. Add 2 to that value (13)
3. *copy* the result of the addition expression *into* the variable on the left, changing counter

```
cout << counter << endl;
```

13 is shown

Constants

- Sometimes the programmer knows certain values just from analyzing the problem, for this kind of information, programmers use the reserved word **`const`**.
- The reserved word **`const`** is used to define a constant.
- A **`const`** is a variable whose contents cannot be changed and must be set when created.
  (Most programmers just call them constants, not variables.)
- Constants are commonly written using capital letters to distinguish them visually from regular variables:

```
const double BOTTLE_VOLUME = 2;
```


Constants

Another good reason for using constants:

```
double volume = bottles * 2;
```

What does that 2 mean?

Constants

If we use a constant there is no question:

```
double volume = bottles * BOTTLE_VOLUME;
```

Any questions?

Constants

And still another good reason for using constants:

```
double bottle_volume = bottles * 2;
double can_volume = cans * 2;
```

What does *that* 2 mean?

— *WHICH 2?*

That 2 is called a "***magic number***"

(so is that one)

because it would require magic to know what 2 means.

It is not good programming practice to use magic numbers. Use constants.

Constants

And it can get even worse …

Suppose that the number 2 appears hundreds of times throughout a five-hundred-line program?

Now we need to change the BOTTLE_VOLUME to 2.23 (because we are now using a bottle with a different shape)

How to change ***only*** some of those magic numbers 2's?

Constants

Constants to the rescue!

```
const double BOTTLE_VOLUME = 2.23;
const double CAN_VOLUME = 2;

...

double bottle_volume = bottles * BOTTLE_VOLUME;
double can_volume = cans * CAN_VOLUME;
```

(Look, no magic numbers!)

Comments

- *Comments* are explanations for human readers of your code (other programmers).
- The compiler ignores comments completely.

```
double can_volume = 0.355; // Liters in a 12-ounce can
```

Comment

Comments

```
double can_volume = 0.355; // Liters in a 12-ounce can
```

Comments

Comments can be written in two styles:

- Single line:

```
double can_volume = 0.355; // Liters in a 12-ounce can
```

The compiler ignores everything after `//` to the end of line

- Multiline for longer comments:

```
/*
   This program computes the volume (in liters)
   of a six-pack of soda cans.
*/
```


Notice All the Issues Covered So Far

ch02/volume1.cpp

```
/*
This program computes the volume (in liters) of a six-pack of soda
cans and the total volume of a six-pack and a two-liter bottle.
*/

int main()
{
   int cans_per_pack = 6;
   const double CAN_VOLUME = 0.355; // Liters in a 12-ounce can
   double total_volume = cans_per_pack * CAN_VOLUME;

   cout << "A six-pack of 12-ounce cans contains "
      << total_volume << " liters." << endl;

   const double BOTTLE_VOLUME = 2; // Two-liter bottle

   total_volume = total_volume + BOTTLE_VOLUME;

   cout << "A six-pack and a two-liter bottle contain "
      << total_volume << " liters." << endl;

   return 0;
}
```

Common Error – Using Undefined Variables

You must define a variable before you use it for the first time. For example, the following sequence of statements would not be legal:

```
double can_volume = 12 * liter_per_ounce;
double liter_per_ounce = 0.0296;
```

Statements are compiled in top to bottom order.

When the compiler reaches the first statement, it does not know that **liter_per_ounce** will be defined in the next line, and it reports an error.

Common Error – Using Uninitialized Variables

Initializing a variable is not required, but there is always a value in every variable, even uninitialized ones. Some value will be there, the flotsam left over from some previous calculation or simply the random value there when the transistors in RAM were first turned on.

```
int bottles; // Forgot to initialize
int bottle_volume = bottles * 2; // Result is unpredictable
```

What value would be output from the following statement?

```
cout << bottle_volume << endl; // Unpredictable
```


Numeric Types in C++

In addition to the **int** and **double** types, C++ has several other numeric types.

C++ has two other floating-point types.

The **float** type uses half the storage of the double type that we use in this book, but it can only store 6–7 digits.

Numeric Types in C++

Many years ago, when computers had far less memory than they have today, **float** was the standard type for floating-point computations, and programmers would *indulge in the luxury of "double precision"* only when they really needed the additional digits.

Ah, the good old days...

Today, the **float** type is rarely used.

The third type is called **long double** and is for quadruple precision. Most contemporary compilers use this type when a programmer asks for a **double** so just choosing **double** is what is done most often.

Numeric Types in C++

By the way, these numbers are called "floating-point" because of their internal representation in the computer.

Consider the numbers 29600, 2.96, and 0.0296. They can be represented in a very similar way: namely, as a sequence of the significant digits: 296 and an indication of the position of the decimal point. When the values are multiplied or divided by 10, only the position of the decimal point changes; it "floats".

Computers use base 2, not base 10, but the principle is the same.

Numeric Types in C++

Table 4 Number Types

Type	Typical Range	Typical Size
int	–2,147,483,648 . . . 2,147,483,647 (about 2 billion)	4 bytes
unsigned	0 . . . 4,294,967,295	4 bytes
short	–32,768 . . . 32,767	2 bytes
unsigned short	0 . . . 65,535	2 bytes
double	The double-precision floating-point type, with a range of about $\pm 10^{308}$ and about 15 significant decimal digits	8 bytes
float	The single-precision floating-point type, with a range of about $\pm 10^{38}$ and about 7 significant decimal digits	4 bytes

Numeric Types in C++

In addition to the **`int`** type, C++ has these additional integer types: **`short`**, **`long`**.
For each integer type, there is an unsigned equivalent: **`unsigned short`**, **`unsigned long`**

For example, the **`short`** type typically has a range from –32,768 to 32,767, whereas **`unsigned short`** has a range from 0 to 65,535. These strange-looking limits are the result of the use of binary numbers in computers.

A **`short`** value uses 16 binary digits, which can encode 2^{16} = 65,536 values.

Numeric Types in C++

The C++ Standard does not completely specify the number of bytes or ranges for numeric types.

Table 4 showed typical values.

Numeric Types in C++

Some compiler manufacturers have added other types like:

`long long`

long long	–9,223,372,036,854,775,808 . . . 9,223,372,036,854,775,807	8 bytes

This type is not in the C++ standard as of this writing.

Numeric Ranges and Precisions

The **`int`** type has a *limited range:*

On most platforms, it can represent numbers up to a little more than two billion.

For many applications, this is not a problem, but you cannot use an **`int`** to represent the world population.

If a computation yields a value that is outside the **`int`** range, the result *overflows.*

No error is displayed.

Instead, the result is *truncated* to fit into an **`int`**, yielding a value that is most likely not what you thought.

Numeric Ranges and Precisions

For example:

```
int one_billion = 1000000000;
cout << 3 * one_billion << endl;
```

displays –1294967296 because the result is larger than an **`int`** can hold.

In situations such as this, you could instead use the **`double`** type.

However, you will need to think about a related issue: *roundoff errors*.

Arithmetic Operators

C++ has the same arithmetic operators as a calculator:

* for multiplication: **`a * b`**
(not **`a · b`** or **`ab`** as in math)

/ for division: **`a / b`**
(not ÷ or a fraction bar as in math)

\+ for addition: **`a + b`**

\- for subtraction: **`a – b`**

Arithmetic Operators

Just as in regular algebraic notation,
* and / have higher precedence
than + and –.

In **`a + b / 2`**,
the **`b / 2`** happens first.

Increment and Decrement

- Changing a variable by adding or subtracting 1 is so common that there is a special shorthand for these:

  The increment and decrement operators.

```
counter++; // add 1 to counter
counter--; // subtract 1 from counter
```


Increment and Decrement

C++ was based on C and so it's one better than C, right?

Guess how C++ got its name!

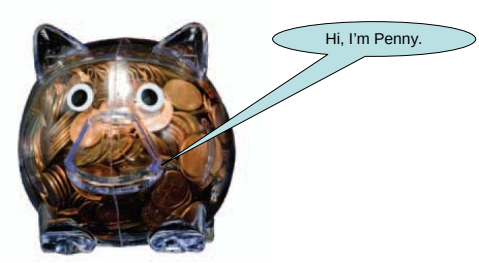
Integer Division and Remainder

The % operator computes the remainder of an integer division.

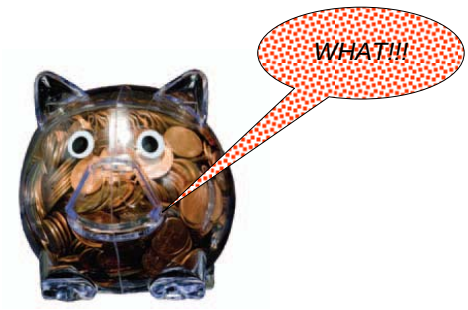
It is called the ***modulus operator***
(also modulo and mod)

It has nothing to do with the % key on a calculator

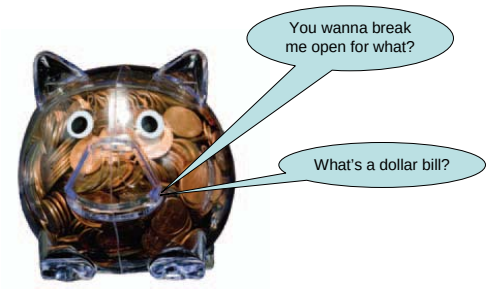
Integer Division and Remainder



Integer Division and Remainder



Integer Division and Remainder



Integer Division and Remainder

Time to break open the piggy bank.

You want to determine the value in dollars and cents stored in the piggy bank.
You obtain the dollars through an integer division by 100.
The integer division discards the remainder.
To obtain the remainder, use the % operator:

```
int pennies = 1729;
int dollars = pennies / 100; // Sets dollars to 17
int cents = pennies % 100; // Sets cents to 29
```

(yes, 100 is a magic number)

Integer Division and Remainder

```
dollars =  / 100;
```

```
cents =  % 100;
```

Don't worry, Penny wasn't broken or harmed in any way because she's on the right hand side of the = operator.

Converting Floating-Point Numbers to Integers

- When a floating-point value is assigned to an integer variable, the fractional part is discarded:

```
double price = 2.55;
int dollars = price;
      // Sets dollars to 2
```

- You probably want to round to the *nearest* integer. To round a positive floating-point value to the nearest integer, add 0.5 and then convert to an integer:

```
int dollars = price + 0.5;
         // Rounds to the nearest integer
```


Powers and Roots

What about this?

$$b + \left(1 + \frac{r}{100}\right)^n$$

Inside the parentheses is easy:

```
1 + (r / 100)
```

But that raised to the *n*?

Powers and Roots

- In C++, there are no symbols for powers and roots. To compute them, you must call *functions*.
- The C++ library defines many mathematical functions such as **`sqrt`** (square root) and **`pow`** (raising to a power).
- To use the functions in this library, called the **`cmath`** library, you must place the line:

```
#include <cmath>
```

at the top of your program file.

- It is also necessary to include

```
using namespace std;
```

at the top of your program file.

Powers and Roots

The power function has the base followed by a comma followed by the power to raise the base to:

```
pow(base, exponent)
```

Using the **pow** function:

```
b * pow(1 + r / 100, n)
```


Powers and Roots

Table 5 Arithmetic Expressions

Mathematical Expression	C++ Expression	Comments
$\frac{x+y}{2}$	`(x + y) / 2`	The parentheses are required; `x + y / 2` computes $x + \frac{y}{2}$.
$\frac{xy}{2}$	`x * y / 2`	Parentheses are not required; operators with the same precedence are evaluated left to right.
$\left(1+\frac{r}{100}\right)^n$	`pow(1 + r / 100, n)`	Remember to add `#include <cmath>` to the top of your program.
$\sqrt{a^2+b^2}$	`sqrt(a * a + b * b)`	`a * a` is simpler than `pow(a, 2)`.
$\frac{i+j+k}{3}$	`(i + j + k) / 3.0`	If i, j, and k are integers, using a denominator of 3.0 forces floating-point division.

Other Mathematical Functions

Table 6 Other Mathematical Functions

Function	Description
`sin(x)`	sine of x (x in radians)
`cos(x)`	cosine of x
`tan(x)`	tangent of x
`log10(x)`	(decimal log) $\log_{10}(x)$, $x > 0$
`abs(x)`	absolute value $\lvert x \rvert$

Common Error – Unintended Integer Division

- If both arguments of / are integers, the remainder is discarded:
  `7 / 3` is **2**, not **`2.5`**
- but
  `7.0 / 4.0`
  `7 / 4.0`
  `7.0 / 4`
- all yield **`1.75`**.

Common Error – Unintended Integer Division

It is unfortunate that C++ uses the same symbol: **/** for both integer and floating-point division. These are really quite different operations.

It is a common error to use integer division by accident. Consider this segment that computes the average of three integers:

```
cout << "Please enter your last three test scores: ";
int s1;
int s2;
int s3;
cin >> s1 >> s2 >> s3;
double average = (s1 + s2 + s3) / 3;
cout << "Your average score is " << average << endl;
```

Error

Common Error – Unintended Integer Division

What could be wrong with that?

Of course, the average of **s1**, **s2**, and **s3** is

```
(s1+ s2+ s3) / 3
```

Here, however, the **/** does not mean division in the mathematical sense.

It denotes integer division because both **`(s1 + s2 + s3)`** and **3** are integers.

Common Error – Unintended Integer Division

For example, if the scores add up to 14,
the average is computed to be 4.

WHAT?

Yes, the result of the integer division of 14 by 3 is 4
How many times does 3 evenly divide into 14?
Right!

That integer 4 is then moved into the floating-point variable **`average`**.

So 4.0 is stored.

That's not what I want!

Common Error – Unintended Integer Division

The remedy is to make the numerator or denominator into a floating-point number:

```
double total = s1 + s2 + s3;
double average = total / 3;
```

or

```
double average = (s1 + s2 + s3) / 3.0;
```


Common Error – Unbalanced Parentheses

Consider the expression

```
(-(b * b - 4 * a * c) / (2 * a)
```

?

What is wrong with it?

The parentheses are *unbalanced*.
This is very common with complicated expressions.

Common Error – Unbalanced Parentheses

Now consider this expression

```
-(b * b - (4 * a * c))) / 2 * a)
```

It is still is not correct.

There are too many closing parentheses.

Common Error – Unbalanced Parentheses – A Solution

The Muttering Method

Count (not out loud, of course!)
starting with 1 at the 1st parenthesis
add one for each **(**
subtract one for each **)**

```
- ( b * b - ( 4 * a * c ) )  ) / 2 * a )
  1         2              1  0  -1
```

OH NO!
(still to yourself – careful!)

If your count is not 0 when you finish, or if you ever drop to -1, STOP, something is wrong.

Common Error – Forgetting Header Files

Every program that carries out input or output needs the **`<iostream>`** header.

If you use mathematical functions such as **`sqrt`**, you need to include **`<cmath>`**.

If you forget to include the appropriate header file, the compiler will not know symbols such as **`cout`** or **`sqrt`**.

If the compiler complains about an undefined function or symbol, check your header files.

Common Error – Forgetting Header Files

Sometimes you may not know which header file to include.

Suppose you want to compute the absolute value of an integer using the **abs** function.

As it happens, this version of **abs** is not defined in the **<cmath>** header but in **<cstdlib>**.

How can you find the correct header file?

Why do you think Tim Berners-Lee invented going online?

A reference site on the Internet such as: http://www.cplusplus.com is a great help.

(Note: do not attempt to click the link if this slide is being projected.)

Common Error – Roundoff Errors

This program produces the wrong output:

```
#include <iostream>
using namespace std;
int main()
{
   double price = 4.35;
   int cents = 100 * price;
         // Should be 100 * 4.35 = 435
   cout << cents << endl;
         // Prints 434!
   return 0;
}
```

Why?

Common Error – Roundoff Errors

- In the processor hardware, numbers are represented in the binary number system, not in decimal.
- In the binary system, there is no exact representation for 4.35, just as there is no exact representation for ⅓ in the decimal system.
  The representation used by the computer is just a little less than 4.35, so 100 times that value is just a little less than 435.
- The remedy is to add 0.5 in order to round to the nearest integer:

```
int cents = 100 * price + 0.5;
```


Spaces in Expressions

It is easier to read

```
x1 = (-b + sqrt(b * b - 4 * a * c)) / (2 * a);
```

than

```
x1=(-b+sqrt(b*b-4*a*c))/(2*a);
```

Itreallyiseasiertoreadwithspaces!

So always use spaces around all operators: **+ - * / % =**

Spaces in Expressions

However, don't put a space after a *unary* minus: that's a **–** used to negate a single quantity like this: **-b**

That way, it can be easily distinguished from a *binary* minus, as in **a - b**

It is customary *not* to put a space after a function name.

Write **sqrt(x)**
not **sqrt (x)**

Casts

Occasionally, you need to store a value into a variable of a different type.

Whenever there is the risk of information loss, the compiler generally issues a warning.

It's not a compilation error to lose information. But it may not be what a programmer intended.

Casts

For example, if you store a **`double`** value into an **`int`** variable, information is lost in two ways:

The fractional part ***will*** be lost.

```
int n = 1.99999; // NO
```

```
1 is stored
(the decimal part is truncated)
```

The magnitude may be too large.

```
int n = 1.0E100; // NO
```

is not likely to work, because 10100 is larger than the largest representable integer.

Casts

A ***cast*** is a conversion from one type (such as **`double`**) to another type (such as **`int`**).

This is not safe in general, but if you know it to be safe in a particular circumstance, casting is the *only* way to do the conversion.

Casts

Nevertheless, sometimes you do want to convert a floating-point value into an integer value.

If you are prepared to lose the fractional part and you know that this particular floating point number is not larger than the largest possible integer, then you can turn off the warning by using a cast.

.

Casts

It's not really about turning off warnings…

Sometimes you *need* to cast a value to a different type.

Consider money.
(A good choice of topic)
(and remember Penny?)

Casts

```
double change; // change owed
change = 999.89;
```

To annoy customers who actually want change when they pay with $10000 bills, we say:

"Sorry, we can only give change in pennies."

(in a pleasantly lilting voice, of course)

How many pennies do we owe them?

We need to cast the change owed into the correct type for pennies.

Casts

A bank would round down to the nearest penny, of course, but we will do the right thing (even to this annoying customer)…

How to "round up" to the next whole penny?

Add 0.5 to the change and then ***cast*** that amount into an **`int`** value, storing the number of pennies into an **`int`** variable.

```
int cents; // pennies owed
```

Casts

You express a cast in C++ using a ***static_cast***

```
static_cast<   >(   )
```


Casts

```
change = 999.89; // change owed

int cents = static_cast<   >(                  );
```


Casts

```
change = 999.89; // change owed

int cents = static_cast<   >(                  );
```

You put the type you want to convert to inside the **< >**

Casts

```
change = 999.89; // change owed

int cents = static_cast<int>(                  );
```

You put the type you want to convert to inside the **< >**

Casts

```
change = 999.89; // change owed

int cents = static_cast<int>(                  );
```

You put the type you want to convert to inside the **< >**

You put the value you want to convert inside the **( )**

Casts

```
change = 999.89; // change owed

int cents = static_cast<int>(100 * change + 0.5);
```

You put the type you want to convert to inside the **< >**

You put the value you want converted inside the **( )**

Casts

```
change = 999.89; // change owed

int cents = static_cast<int>(100 * change + 0.5);
```

You put the type you want to convert to inside the **< >**

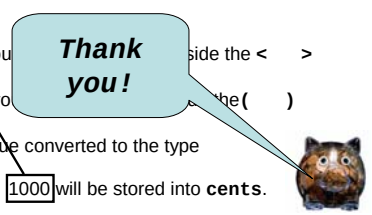
You put the value you want to convert inside the **( )**

and you get the value converted to the type: 1000 pennies

Casts

```
change = 999.89; // change owed

int cents = static_cast<int>(100 * change + 0.5);
```



You put the type you ide the **< >**

You put the value yo he **( )**

and you get the value converted to the type

1000 will be stored into **cents**.

Combining Assignment and Arithmetic

In C++, you can combine arithmetic and assignments.
For example, the statement

```
total += cans * CAN_VOLUME;
```

is a shortcut for

```
total = total + cans * CAN_VOLUME;
```

Similarly,

```
total *= 2;
```

is another way of writing

```
total = total * 2;
```

Many programmers *prefer* using this form of coding.

Input

- Sometimes the programmer does not know what should be stored in a variable – but the user does.
- The programmer must get the input value from the user
  - Users need to be prompted
    (how else would they know they need to type something?
  - Prompts are done in output statements
- The keyboard needs to be read from
  - This is done with an input statement

Input

The input statement

- To read values from the keyboard, you input them from an object called **cin**.
- The **<<** operator denotes the "send to" command.

```
cin >> bottles;
```

is an *input statement*.

Of course, **bottles** must be defined earlier.

Input

You can read more than one value in a single input statement:

```
cout << "Enter the number of bottles and cans: ";
cin >> bottles >> cans;
```

The user can supply both inputs on the same line:

```
Enter the number of bottles and cans: 2 6
```

Input

You can read more than one value in a single input statement:

```
cout << "Enter the number of bottles and cans: ";
cin >> bottles >> cans;
```

Alternatively, the user can press the Enter key after each input:

```
Enter the number of bottles and cans: 2
6
```


Input Statement

Syntax 2.3 Input Statement

Don't use endl here.

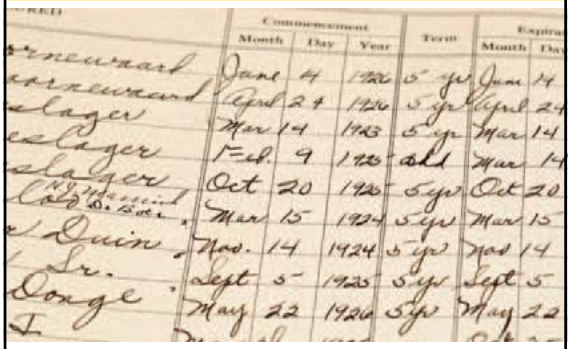
Display a prompt in the console window.

Define a variable to hold the input value.

The program waits for user input, then places the input into the variable.

```
cout << "Enter the number of bottles: ";
int bottles;
cin >> bottles;
```


Formatted Output



Formatted Output

- When you print an amount in dollars and cents, you usually want it to be *rounded* to two significant digits.
- You learned how to actually round off and store a value but, for output, we want to round off *only* for display.
- A ***manipulator*** is something that is sent to **`cout`** to specify how values should be formatted.
- To use manipulators, you must include the **`iomanip`** header in your program:

  ```
  #include <iomanip>
  ```

  and

  ```
  using namespace std;
  ```

  is also needed

Formatted Output

Which do you think the user prefers to see on her gas bill?

```
Price per liter: $1.22
```

or

```
Price per liter: $1.21997
```


Formatted Output

Table 7 Formatting Output

Output Statement	Output	Comment
`cout << 12.345678;`	`12.3457`	By default, a number is printed with 6 significant digits.
`cout << fixed << setprecision(2) << 12.3;`	`12.30`	Use the `fixed` and `setprecision` manipulators to control the number of digits after the decimal point.
`cout << ":" << setw(6) << 12;`	`:  12`	Four spaces are printed before the number, for a total width of 6 characters.
`cout << ":" << setw(2) << 123;`	`:123`	If the width not sufficient, it is ignored.
`cout << setw(6) << ":" << 12;`	`:12.3`	The width only refers to the next item. Here, the : is preceded by five spaces.

Formatted Output

You can combine manipulators and values to be displayed into a single statement:

```
price_per_liter = 1.21997;
cout << fixed << setprecision(2)
   << "Price per liter: $"
   << price_per_liter << endl;
```

This code produces this output:

```
Price per liter: $1.22
```


Formatted Output

You use the **`setw`** manipulator to set the *width* of the next output field.

The width is the total number of characters used for showing the value, including digits, the decimal point, and spaces.

Formatted Output

If you want columns of certain widths, use the **`setw`** manipulator.

For example, if you want a number to be printed, right justified, in a column that is eight characters wide, you use

```
<< setw(8)
```


Formatted Output

This code:

```
price_per_ounce_1 = 10.2372;
price_per_ounce_2 = 117.2;
price_per_ounce_3 = 6.9923435;
cout << setprecision(2);
cout << setw(8) << price_per_ounce_1;
cout << setw(8) << price_per_ounce_2;
cout << setw(8) << price_per_ounce_3;
cout << "--------" << endl;
```

produces this output:

```
   10.24
  117.20
    6.99
--------
```


Formatted Output

There is a notable difference between the **`setprecision`** and **`setw`** manipulators.

Once you set the precision, that width is used for all floating-point numbers until the next time you set the precision.

But **`setw`** affects only the *next* value.

Subsequent values are formatted without added spaces.

A Complete Program for Volumes

ch02/volume2.cpp

```
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   // Read price per pack

   cout << "Please enter the price for a six-pack: ";
   double pack_price;
   cin >> pack_price;

   // Read can volume

   cout << "Please enter the volume for each can (in ounces): ";
   double can_volume;
   cin >> can_volume;
```

A Complete Program for Volumes

ch02/volume2.cpp

```
// Compute pack volume

const double CANS_PER_PACK = 6;
double pack_volume = can_volume * CANS_PER_PACK;

// Compute and print price per ounce

double price_per_ounce = pack_price / pack_volume;

cout << fixed << setprecision(2);
cout << "Price per ounce: " << price_per_ounce << endl;

return 0;
}
```


Strings

- Strings are sequences of characters:

```
"Hello world"
```

- If you include the string header, you can create variables to hold literal strings:

```
#include <string>
using namespace std;
...
string name = "Harry";
       // literal string "Harry" stored
```


Strings

- String variables are guaranteed to be initialized even if you don't initialize them:

```
string response;
       // literal string "" stored
```

- `""` is called the empty or null string.

Concatenation

Use the **+** operator to *concatenate* strings; that is, put them together to yield a longer string.

```
string fname = "Harry";
string lname = "Morgan";
string name = fname + lname;
cout << name << endl;
name = fname + " " + lname;
cout << name << endl;
```

The output will be

```
HarryMorgan
Harry Morgan
```


Common Error – Concatenation of literal strings

```
string greeting = "Hello, " + " World!";
                  // will not compile
```

Literal strings cannot be concatenated.

String Input

You can read a string from the console:

```
cout << "Please enter your name: ";
string name;
cin >> name;
```

When a string is read with the **>>** operator, only one word is placed into the **`string`** variable.

For example, suppose the user types

```
Harry Morgan
```

as the response to the prompt.
This input consists of two words.
Only the string "Harry" is placed into the variable name.

String Input

You can use another input to read the second word.

```
cout << "Please enter your name: ";
string fname, lname;
cin >> fname >> lname;
```

gets `Harry` gets `Morgan`

String Functions

- The **`length`** *member function* yields the number of characters in a string.
- Unlike the **`sqrt`** or **`pow`** function, the **`length`** function is *invoked* with the *dot notation*:

```
int n = name.length();
```


String Functions

- Once you have a string, you can extract substrings by using the **`substr`** member function.
- **`s.substr(start, length)`** returns a **`string`** that is made from the characters in the **`string s`**, starting at character **`start`**, and containing **`length`** characters. (**`start`** and **`length`** are integer values).

```
string greeting = "Hello, World!";
string sub = greeting.substr(0, 5);
   // sub contains "Hello"
```


String Functions

0 ?

```
string sub = greeting.substr(0, 5);
```


String Functions

```
string greeting = "Hello, World!";
string w = greeting.substr(7, 5);
   // w contains "World" (not the !)
```

`"World"` is 5 characters long but…
why is 7 the position of the "W" in **`"World"`**?

0 ?

String Functions

H	e	l	l	o	,		W	o	r	l	d	!
0	1	2	3	4	5	6	7	8	9	10	11	12

In most computer languages, the starting position 0 means "start at the beginning."

The first position in a string is labeled 0, the second one 1, and so on. And don't forget to count the space character after the comma—but the quotation marks are ***not*** stored.

String Functions

```
H  e  l  l  o  ,     W  o  r  l  d  !
0  1  2  3  4  5  6  7  8  9  10 11 12
```

The position number of the last character is always one less than the length of the string

The `!` is at position 12 in **`"Hello, World!"`**.
The length of **`"Hello, World!"`** is 13.

(C++ remembers to count the 0 as one of the positions when counting characters in strings.)

String Functions

```
H  e  l  l  o  ,     W  o  r  l  d  !
0  1  2  3  4  5  6  7  8  9  10 11 12
```

```
string greeting = "Hello, World!";
string w = greeting.substr(7);
   // w contains "World!"
```

If you do not specify how many characters to take, you get all the rest.

String Functions

```
H  e  l  l  o  ,     W  o  r  l  d  !
0  1  2  3  4  5  6  7  8  9  10 11 12
```

```
string greeting = "Hello, World!";
string w = greeting.substr();
// w contains "Hello World!"
```

If you omit the starting position and the length, you get all the characters

(not much of *sub*string!)

String Operations

Statement	Result	Comment
`string str = "C";` `str = str + "++";`	`str` is set to `"C++"`	When applied to strings, + denotes concatenation.
`string str = "C" + "++";`	Error	**Error:** You cannot concatenate two string literals.

`cout << "Enter name: ";`
`cin >> name;`
(User input: Harry Morgan)
	`name` contains `"Harry"`	The >> operator places the next word into the `string` variable.

`cout << "Enter name: ";`
`cin >> name >> last_name;`
(User input: Harry Morgan)
	`name` contains `"Harry"`, `last_name` contains `"Morgan"`	Use multiple >> operators to read more than one word.

`string greeting = "H & S";` `int n = greeting.length();`	`n` is set to 5	Each space counts as one character.

String Operations

Statement	Result	Comment
`string str = "Sally";` `string str2 = str.substr(1, 3);`	`str2` is set to `"all"`	Extracts the substring of length 3 starting at position 1. (The initial position is 0.)
`string str = "Sally";` `string str2 = str.substr(1);`	`str2` is set to `"ally"`	If you omit the length, all characters from the position until the end are included.
`string a = str.substr(0, 1);`	`a` is set to the initial letter in `str`	Extracts the substring of length 1 starting at position 0.
`string b = str.substr(` `  str.length() - 1);`	`b` is set to the last letter in `str`	The last letter has position `str.length() - 1`. We need not specify the length.

String Functions

Write this code

String Functions

ch02/initials.cpp

```
#include <iostream>
#include <string>
using namespace std;

int main()
{
   cout << "Enter your first name: ";
   string first;
   cin >> first;
   cout << "Enter your significant other's first name: ";
   string second;
   cin >> second;
   string initials = first.substr(0, 1)
      + "&" + second.substr(0, 1);
   cout << initials << endl;

   return 0;
}
```


Chapter Summary

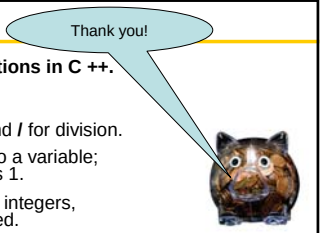
Write variable definitions in C++.

- A variable is a storage location with a name.
- When defining a variable, you usually specify an initial value.
- When defining a variable, you also specify the type of its values.
- Use the **`int`** type for numbers that cannot have a fractional part.
- Use the **`double`** type for floating-point numbers.

Chapter Summary

- An assignment statement stores a new value in a variable, replacing the previously stored value.
- The assignment operator **=** does *not* denote mathematical equality.
- You cannot change the value of a variable that is defined as **`const`**.
- Use comments to add explanations for humans who read your code. The compiler ignores comments.

Chapter Summary



Use the arithmetic operations in C ++.

- Use ***** for multiplication and **/** for division.
- The **++** operator adds 1 to a variable; the **--** operator subtracts 1.
- If both arguments of **/** are integers, the remainder is discarded.
- The **%** operator computes the remainder of an integer division.
- Assigning a floating-point variable to an integer drops the fractional part.
- The C++ library defines many mathematical functions such as **`sqrt`** (square root) and **`pow`** (raising to a power).

Chapter Summary

Write programs that read user input and write formatted output.

- Use the **>>** operator to read a value and place it in a variable.
- You use manipulators to specify how values should be formatted.

Carry out hand calculations when developing an algorithm.

- Pick concrete values for a typical situation to use in a hand calculation.

Chapter Summary

Write programs that process strings.

- Strings are sequences of characters
- Use the **+** operator to concatenate strings; that is, put them together to yield a longer string.
- The **`length`** member function yields the number of characters in a string.
- A member function is invoked using the dot notation.
- Use the **`substr`** member function to extract a substring of a string.

End Chapter Two