Chapter 2 - Variables / Assignments

Section 2.1 - Variables (int)

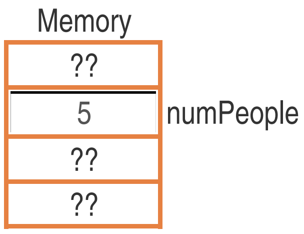
Here's a variation on a common schoolchild riddle.

P Participation Activity | 2.1.1: People on bus.

For each step, keep track of the current number of people by typing in the numPeople box (it's editable).

Start

```
You are driving a bus.
The bus starts with 5 people.
```



1	2	3	4	5

Check Next

You used that box to remember the number of people as you proceeded through each step. Likewise, a program uses a *variable* to remember values as the program executes instructions. (By the way, the real riddle's ending question is actually "What is the bus driver's name?"— the subject usually says "How should I know?". The riddler then says "I said, YOU are driving a bus.")

A ***variable*** represents a memory location used to store data. That location is like the "box" that you used above. The statement `int userAge;` ***defines*** (also called ***declares***) a new variable named userAge. The compiler allocates a memory location for userAge capable of storing an integer, hence the "int". When a statement executes that assigns a value to a variable, the processor stores the value into the variable's memory location. Likewise, reading a variable's value reads the value from the variable's memory location.[mem] The animation illustrates.

Participation Activity

2.1.2: A variable refers to a memory location.

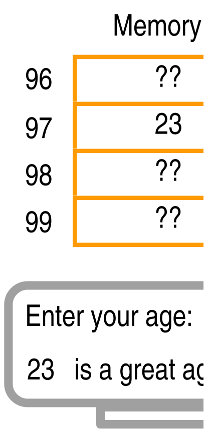
Start

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

int main() {
   int userAge = 0;

   cout << "Enter your age: ";
   cin >> userAge;
   cout << userAge << " is a great age." << endl;

   return 0;
}
```



```
Enter your age:
23  is a great ag
```

In the animation, the compiler allocated variable userAge to memory location 97, known as the variables ***address***; the choice of 97 is arbitrary, and irrelevant to the programmer (but the idea of a memory location is important to understand). The animation shows memory locations 96-99; a real memory will have thousands, millions, or even billions of locations.

Although not required, an integer variable is commonly assigned an initial value when defined.

Construct 2.1.1: Basic integer variable definition with initial value of 0.

```
int variableName = 0;
```

P Participation Activity

2.1.3: Defining integer variables.

Note: Capitalization matters, so MyNumber is not the same as myNumber.

#	Question	Your answer
1	Define an integer variable named numPeople. Do not initialize the variable.	
2	Define an integer variable named numDogs, initializing the variable to 0 in the definition.	
3	Define an integer variable named daysCount, initializing the variable to 365 in the definition.	
4	What memory location (address) will a compiler allocate for the variable definition: int numHouses = 99; If appropriate, type: Unknown	

The programmer must define a variable *before* any statement that assigns or reads the variable, so that the variable's memory location is known.

A variable definition is also commonly called a variable ***declaration***. This material may use either term.

P Participation Activity

2.1.4: Defining a variable.

Define a second integer variable avgLifespan, initialized to 70. Add a statement that prints "Average lifespan is 70" (don't type 70 there; print the avgLifespan variable).

```

#include <iostream>
using namespace std;

int main() {
   int userAge = 0;
   // Define new variable here

   cout << "Enter your age: " << endl;
   cin >> userAge;
   cout << userAge << " is a great age." << endl;

   // Add new print statement here

   return 0;
}

```

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Run

A common error is to read a variable that has not yet been assigned a value. If a variable is defined but not initialized, the variable's memory location contains some unknown value, commonly but not always 0. A program with an uninitialized variable may thus run correctly on system that has 0 in the memory location, but then fail on a different system—a very difficult bug to fix. Programmers thus must ensure that a program assigns a variable before reading. A good practice is to initialize a variable in its definition whenever practical. The space allocated to a variable in memory is not infinite. An int variable can usually only hold numbers in the range -2,147,483,648 to 2,147,483,647. That's about ±2 billion.

P Participation Activity

2.1.5: int variables.

Which statement is an error?

#	Question	Your answer
1	int dogCount;	Error No error
2	int amountOwed = -999;	Error No error
3	int numYears = 9000111000;	Error No error

Multiple variables can be defined in the same statement, as in: `int numProtons, numNeutrons, numElectrons;`. This material usually avoids such style, especially when definition initializes the variable (which may be harder to see otherwise).

C Challenge Activity

2.1.1: Declaring variables.

Write one statement that declares an integer variable numHouses initialized to 25.

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

int main() {

   /* Your solution goes here  */

   cout << numHouses << endl;

   return 0;
}
```

Run

(*mem) Instructors: Although compilers may optimize variables away or store them on the stack or in a register, the conceptual view of a variable in memory helps understand many language aspects.

Section 2.2 - Assignments

An ***assignment statement*** like `numApples = 8;` stores (i.e. assigns) the right-side item's current value (in this case, 8) into the variable on left side (numApples).asgn

Construct 2.2.1: Assignment statement.

```
variableName = expression;
```

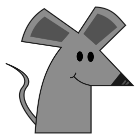
An ***expression*** may be a number like 80, a variable name like numApples, or a simple calculation like numApples + 1. Simple calculations can involve standard math operators like +, -, and *, and parentheses as in 2 * (numApples - 1). Another section describes expressions further.

Figure 2.2.1: Assigning a variable.

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

int main() {
   int litterSize    = 3; // Low end of litter size range
   int yearlyLitters = 5; // Low end of litters per year
   int annualMice    = 0;

   cout << "One female mouse may give birth to ";
   annualMice = litterSize * yearlyLitters;
   cout << annualMice << " mice," << endl;

   litterSize    = 14; // High end
   yearlyLitters = 10; // High end
   cout << "and up to ";
   annualMice = litterSize * yearlyLitters;
   cout << annualMice << " mice, in a year." << endl;

   return 0;
}
```

```
One female mouse may gi
and up to 140 mice, in
```

All three variables are initialized, with annualMice initialized to 0. Later, the value of litterSize * yearlyLitters (3 * 5, or 15) is assigned to annualMice, which is then printed. Next, 14 is assigned to litterSize, and 10 to yearlyLitters, and their product (14 * 10, or 140) is assigned to annualMice, which is printed.



P Participation Activity

2.2.1: Trace the variable value.

Select the correct value for x, y, and z after the following code executes.

Start

```
int x = 4;
int y = 9;
int z = 9;
x = 0;
y = 5;
z = 0;
x = 6;
```

x is

6	4	0

y is

9	5	8

z is

0	6	9

1 2 3 4

Check Next

P Participation Activity

2.2.2: Assignment statements.

Be sure to end assignment statements with a semicolon ;.

#	Question	Your answer
1	Write an assignment statement to assign 99 to numCars.	
2	Assign 2300 to houseSize.	
	Assign the current value of	

3	Assign the current value of numApples to numFruit.	
4	The current value in houseRats is 200. Then: `numRodents = houseRats;` executes. You know 200 will be stored in numRodents. What is the value of *houseRats* after the statement executes? Valid answers: 0, 199, 200, or unknown.	
5	Assign the result of ballCount - 3 to numItems.	
6	dogCount is 5. After `animalsTotal = dogCount - 3;` executes, what is the value in animalsTotal?	
7	dogCount is 5. After `animalsTotal = dogCount - 3;` executes, what is the value in *dogCount*?	
8	What is the value of numBooks after both statements execute? `numBooks = 5;` `numBooks = 3;`	

A common error among new programmers is to assume = means equals, as in mathematics. In contrast, =

means "compute the value on the right, and then assign that value into the variable on the left." Some languages use := instead of = to reduce confusion. Programmers sometimes speak numItems = numApples as "numItems EQUALS numApples", but this material strives to avoid such inaccurate wording.

Another common error by beginning programmers is to write an assignment statement in reverse, as in: numKids + numAdults = numPeople, or 9 = beansCount. Those statements won't compile. But, writing numCats = numDogs in reverse *will* compile, leading to a hard-to-find bug.

Commonly, a variable appears on both the right and left side of the = operator. If numItems is initially 5, then after `numItems = numItems + 1`, numItems will be 6. The statement reads the value of numItems (5), adds 1, and stores the result of 6 in numItems—*overwriting* whatever value was previously in numItems.

P Participation Activity

2.2.3: Assigning to a variable overwrites its previous values: People-known example.

(The above example relates to the popular idea that any two people on earth are connected by just "six degrees of separation", accounting for overlapping of known-people.

P Participation Activity

2.2.4: Assignment statements with same variable on both sides.

#	Question	Your answer
1	numApples is initially 5. What is numApples after: `numApples = numApples + 3;`	

2	numApples is initially 5. What is numFruit after:
	`numFruit  = numApples;`
	`numFruit  = numFruit + 1;`	

3	Write a statement ending with - 1 that decreases variable flyCount's value by 1.	

P Participation Activity

2.2.5: Variable assignments.

Give the final value of z after the statements execute.

#	Question	Your answer

1	`w = 1;`
	`y = 2;`
	`z = 4;`
	
	`x = y + 1;`
	`w = 2 - x;`
	`z = w * y;`	

2	`x = 4;`
	`y = 0;`
	`z = 3;`
	
	`x = x - 3;`
	`y = y + x;`
	`z = z * y;`	

3	`x = 6;`
	`y = -2;`
	
	`y = x + x;`
	`w = y * x;`
	`z = w - y;`	

4	`w = -2;`
	`x = -7;`
	`y = -8;`
	
	`z = x - y;`
	`z = z * w;`
	`z = z / w;`	

C Challenge Activity

2.2.1: Enter the output of the variable assignments.

Start

Enter the output of the following program.

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

int main() {
   int x = 0;
   int y = 6;

   x = 7;

   cout << x << " " << y;

   return 0;
}
```

```
7 6
```

1	2	3	4	5	6

Check Next

C Challenge Activity

2.2.2: Assigning a value.

Write a statement that assigns 3 to hoursLeft.

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

int main() {
   int hoursLeft = 0;

   /* Your solution goes here  */

   cout << hoursLeft << " hours left." << endl;

   return 0;
}
```

Run

C Challenge Activity

2.2.3: Assigning a sum.

Write a statement that assigns numNickels + numDimes to numCoins. Ex: 5 nickels and 6

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

int main() {
   int numCoins    = 0;
   int numNickels = 0;
   int numDimes    = 0;

   numNickels = 5;
   numDimes = 6;

   /* Your solution goes here  */

   cout << "There are  " << numCoins << " coins" << endl;

   return 0;
}
```

Run

C Challenge Activity

2.2.4: Adding a number to a variable.

Write a statement that increases numPeople by 5. If numPeople is initially 10, then numPe

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

int main() {
   int numPeople = 0;

   numPeople = 10;

   /* Your solution goes here  */

   cout << "There are  " << numPeople << " people." << endl;

   return 0;
}
```

Run

(*asgn) We ask instructors to give us leeway to teach the idea of an "assignment statement," rather than the language's actual "assignment expression," whose use we condone primarily in a simple statement.

Section 2.3 - Identifiers

A name created by a programmer for an item like a variable or function is called an ***identifier***. An identifier must be a sequence of letters (a-z, A-Z, _) and digits (0-9) and must start with a letter. Note that "_", called an ***underscore***, is considered to be a letter.

The following are valid identifiers: c, cat, Cat, n1m1, short1, and _hello. Note that cat and Cat are different identifiers. The following are invalid identifiers: 42c (starts with a digit), hi there (has a disallowed symbol: space), and cat! (has a disallowed symbol: !).

A ***reserved word*** is a word that is part of the language, like int, short, or double. A reserved word is also known as a ***keyword***. A programmer cannot use a reserved word as an identifier. Many language editors will automatically color a program's reserved words. A list of reserved words appears at the end of this section.

P Participation Activity

2.3.1: Valid identifiers.

Which are valid identifiers?

#	Question	Your answer
1	numCars	Valid Invalid
2	num_Cars1	Valid Invalid
3	_numCars	Valid Invalid
4	___numCars	Valid Invalid
5	num cars	Valid Invalid
6	3rdPlace	Valid Invalid
7	thirdPlace_	Valid Invalid

8	thirdPlace!	Valid Invalid
9	tall	Valid Invalid
10	short	Valid Invalid
11	very tall	Valid Invalid

P Participation Activity

2.3.2: Identifier validator.

Note: Doesn't consider library items.

Try an identifier: Validate

Awaiting your input...

Identifiers are ***case sensitive***, meaning upper and lower case letters differ. So numCats and NumCats are different.

While various (crazy-looking) identifiers may be valid, programmers follow identifier ***naming conventions*** (style) defined by their company, team, teacher, etc. Two common conventions for naming variables are:

- Camel case: ***Lower camel case*** abuts multiple words, capitalizing each word except the first, as in numApples or peopleOnBus.

- Underscore separated: Words are lowercase and separated by an underscore, as in num_apples or people_on_bus.

This material uses lower camel case; neither convention is better. The key is to be consistent. Consistent style makes code easier to read and maintain, especially if multiple programmers will be maintaining the code.

Programmers should follow the good practice of creating meaningful identifier names that self-describe an item's purpose. Meaningful names make programs easier to maintain. The following are fairly meaningful: userAge, houseSquareFeet, and numItemsOnShelves. The following are less meaningful: age (whose age?), sqft (what's that stand for?), num (almost no info). Good practice minimizes use of abbreviations in identifiers except for well-known ones like num in numPassengers. Abbreviations make programs harder to read and can also lead to confusion, such as if a chiropractor application involves number of messages and number of massages, and one is abbreviated numMsgs (which is it?).

This material strives to follow another good practice of using two or more words per variable such as numStudents rather than just students, to provide meaningfulness, to make variables more recognizable when they appear in writing like in this text or in a comment, and to reduce conflicts with reserved words or other already-defined identifiers.

While meaningful names are important, very long variable names, such as averageAgeOfUclaGraduateStudent, can make subsequent statements too long and thus hard to read. Programmers strive to find a balance.

P Participation Activity

2.3.3: Meaningful identifiers.

Choose the "best" identifier for a variable with the stated purpose, given the above discussion (including this material's variable naming convention).

#	Question	Your answer
1	The number of students attending UCLA.	num
		numStdsUcla
		numStudentsUcla
		numberOfStudentsAttendingUcla
2	The size of an LCD monitor	size
		sizeLcdMonitor
		s
		sizeLcdMtr
3	The number of jelly beans in a jar.	numberOfJellyBeansInTheJar
		JellyBeansInJar
		jellyBeansInJar
		nmJlyBnsInJr

Table 2.3.1: C++ reserved words / keywords.

alignas (since C++11)	enum	return
alignof (since C++11)	explicit	short
and	export	signed
and_eq	extern	sizeof
asm	false	static
auto(changed C++11)	float	static_assert(since C++11)
bitand	for	static_cast
bitor	friend	struct
bool	goto	switch
break	if	template
case	inline	this
catch	int	thread_local(since C++11)
char	long	throw
char16_t(since C++11)	mutable	true
char32_t(since C++11)	namespace	try
class	new	typedef
compl	noexcept(since C++11)	typeid
const	not	typename
constexpr(since C++11)	not_eq	union
const_cast	nullptr (since C++11)	unsigned
continue	operator	using(changed C++11)
decltype(since C++11)	or	virtual
default(changed C++11)	or_eq	void
delete(changed C++11)	private	volatile
do	protected	wchar_t
double	public	while
dynamic_cast	register	xor
else	reinterpret_cast	xor_eq

Source: http://en.cppreference.com/w/cpp/keyword.

Section 2.4 - Arithmetic expressions (int)

An ***expression*** is a combination of items, like variables, literals, and operators, that evaluates to a value. An example is: 2 * (numItems + 1). If numItems is 4, then the expression evaluates to 2 * (4 + 1) or 10. A ***literal*** is a specific value in code like 2. Expressions occur in variable definitions and in assignment statements (among other places).

Figure 2.4.1: Example expressions in code.

```
int numKids  = 0;                      // Expr: 0
numKids      = 7;                      // Expr: 7
numPeople    = numKids + numAdults;    // Expr: numKids + numAdults
totOffers    = jobsCA + (2 * jobsAZ); // Expr: jobsCA + (2 * jobsAZ)
xCoord       = yCoord;                 // Expr: yCoord
xCoord       = -yCoord;                // Expr: -yCoord
```

Note that an expression can be just a literal, just a variable, or some combination of variables, literals, and operators.

Commas are not allowed in an integer literal. So 1,333,555 is written as 1333555.

P Participation Activity | 2.4.1: Expression in statements.

#	Question	Your answer
1	Is the following an expression? `12`	Yes No
2	Is the following an expression? `int eggsInCarton`	Yes No
3	Is the following an expression? `eggsInCarton * 3`	Yes No
4	Is the following an error? An int's maximum value is 2,147,483,647. numYears = 1,999,999,999;	Yes No

An ***operator*** is a symbol for a built-in language calculation like + for addition. ***Arithmetic operators*** built into the language are:

Table 2.4.1: Arithmetic operators.

Arithmetic operator	Description
+	***addition***
-	***subtraction***
*****	***multiplication***
/	***division***
%	***modulo (remainder)***

Modulo may be unfamiliar and is discussed further below.

Parentheses may be used, as in: ((userItems + 1) * 2) / totalItems. Brackets [ ] or braces { } may NOT be used.

Expressions mostly follow standard arithmetic rules, such as order of evaluation (items in parentheses first, etc.). One notable difference is that the language does *not* allow the multiplication shorthand of abutting a number and variable, as in 5y to represent 5 times y.

P Participation Activity

2.4.2: Capturing behavior with an expressions.

Does the expression correctly capture the intended behavior?

#	Question	Your answer
1	6 plus numItems: `6 + numItems`	Yes / No
2	6 times numItems: `6 x numItems`	Yes / No
	totDays divided by 12:	Yes

3	`totDays / 12`	No
4	5 times i: `5i`	Yes No
5	The negative of userVal: `-userVal`	Yes No
6	itemsA + itemsB, divided by 2: `itemsA + itemsB / 2`	Yes No
7	n factorial `n!`	Yes No

Figure 2.4.2: Expressions examples: Leasing cost.

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

/* Computes the total cost of leasing a car given the down payment,
   monthly rate, and number of months
*/

int main() {
   int downpayment     = 0;
   int paymentPerMonth = 0;
   int numMonths       = 0;
   int totalCost       = 0;  // Computed total cost to be output

   cout << "Enter down payment: " << endl;
   cin  >> downpayment;

   cout << "Enter monthly payment: " << endl;
   cin  >> paymentPerMonth;

   cout << "Enter number of months: " << endl;
   cin  >> numMonths;

   totalCost = downpayment + (paymentPerMonth * numMonths);

   cout << "Total cost: " << totalCost << endl;

   return 0;
}
```

```
Enter down pa
500
Enter monthly
300
Enter number
60
Total cost: 1
```

A good practice is to include a single space around operators for readability, as in numItems + 2, rather than numItems+2. An exception is - used as negative, as in: xCoord = -yCoord. - used as negative is known as ***unary minus***.

P Participation Activity

2.4.3: Single space around operators.

Retype each statement to follow the good practice of a single space around operators.

#	Question	Your answer
1	`housesCity = housesBlock *10;`	
2	`x = x1+x2+2;`	
3	`numBalls=numBalls+1;`	
4	`numEntries = (userVal+1)*2;`	

When the / operands are integers, the division operator / performs integer division, throwing away any remainder. Examples:

- 24 / 10 is 2.
- 50 / 50 is 1.
- 1 / 2 is 0. 2 divides into 1 zero times; remainder of 1 is thrown away.

A common error is to forget that a fraction like (1 / 2) in an expression performs integer division, so the expression evaluates to 0.

The modulo operator % may be unfamiliar to some readers. The modulo operator evaluates to the remainder of the division of two integer operands. Examples:

- 24 % 10 is 4. Reason: 24 / 10 is 2 with remainder 4.
- 50 % 50 is 0. Reason: 50 / 50 is 1 with remainder 0.
- 1 % 2 is 1. Reason: 1 / 2 is 0 with remainder 1.

Figure 2.4.3: Division and modulo example: Minutes to hours/minutes.

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

int main() {
   int userMinutes = 0;  // User input: Minutes
   int outHours    = 0;  // Output hours
   int outMinutes  = 0;  // Output minutes (remaining)

   cout << "Enter minutes: " << endl;
   cin  >> userMinutes;

   outHours    = userMinutes / 60;
   outMinutes = userMinutes % 60;

   cout << userMinutes << " minutes is ";
   cout << outHours    << " hours and ";
   cout << outMinutes  << " minutes." << endl;

   return 0;
}
```

```
Enter minutes:
367
367 minutes is 6 hours and

...

Enter minutes:
180
180 minutes is 3 hours and
```

For integer division, the second operand of / or % must never be 0, because division by 0 is mathematically undefined. A ***divide-by-zero error*** occurs at runtime if a divisor is 0, causing a program to terminate.

Figure 2.4.4: Divide-by-zero example: Compute salary per day.

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

int main() {
   int salaryPerYear = 0; // User input: Yearly salary
   int daysPerYear   = 0; // User input: Days worked per year
   int salaryPerDay  = 0; // Output:     Salary per day

   cout << "Enter yearly salary:" << endl;
   cin  >> salaryPerYear;

   cout << "Enter days worked per year:" << endl;
   cin  >> daysPerYear;

   // If daysPerYear is 0, then divide-by-zero causes program termination.
   salaryPerDay = salaryPerYear / daysPerYear;

   cout << "Salary per day is: " << salaryPerDay << endl;

   return 0;
}
```

```
Enter
60000
Enter
0
Floati
```

P Participation Activity

2.4.4: Integer division and modulo.

Determine the result. Type "Error" if the program would terminate due to divide-by-zero. Only literals appear in these expressions to focus attention on the operators; most practical expressions include variables.

#	Question	Your answer
1	`13 / 3`	
2	`4 / 9`	
3	`(5 +  10 + 15) * (1 / 3)`	
4	`50 % 2`	
5	`51 % 2`	
6	`78 % 10`	
7	`596 % 10`	
8	`100 / (1 / 2)`	

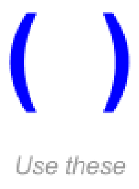
The compiler evaluates an expression's arithmetic operators using the order of standard mathematics, such order known in programming as ***precedence rules***.

Table 2.4.2: Precedence rules for arithmetic operators.

Convention	Description	Explanation
( )	Items within parentheses are evaluated first	In `2 * (A + 1)`, A + 1 is computed first, with the result then multiplied by 2.
unary -	- used as a negative (unary minus) is next	In `2 * -A`, -A is computed first, with the result then multiplied by 2.
*** / %**	Next to be evaluated are *, /, and %, having equal precedence.	
+ -	Finally come + and - with equal precedence.	In `B = 3 + 2 * A`, 2 * A is evaluated first, with the result then added to 3, because * has higher precedence than +. Note that spacing doesn't matter: `B = 3+2 * A` would still evaluate 2 * A first.
left-to-right	If more than one operator of equal precedence could be evaluated, evaluation occurs left to right.	In `B = A * 2 / 3`, A * 2 is first evaluated, with the result then divided by 3.

A common error is to omit parentheses and assume an incorrect order of evaluation, leading to a bug. For example, if x is 3, `5 * x + 1` might appear to evaluate as `5 * (3+1)` or `20`, but actually evaluates as `(5 * 3) + 1` or `16` (spacing doesn't matter). Good practice is to use parentheses to make order of evaluation explicit, rather than relying on precedence rules, as in: y = (m * x) + b, unless order doesn't matter as in x + y + z.

Figure 2.4.5: Post about parentheses.



(Poster A): Tried rand() % (35 - 18) + 18, but it's wrong.

(Poster B): I don't understand what you're doing with (35 - 18) + 18. Wouldn't that just be 35?

(Poster C): The % operator has higher precedence than the + operator. So read that as (rand() % (35 - 18)) + 18.

P Participation Activity | 2.4.5: Precedence rules.

Select the expression whose parentheses enforce the compiler's evaluation order for the original expression.

#	Question	Your answer
1	y + 2 * z	(y + 2) * z y + (2 * z)
2	z / 2-x	(z / 2) - x z / (2 - x)
3	x * y * z	(x * y) * z x * (y * z)
4	x + y % 3	(x + y) % 3 x + (y % 3)
5	x + 1 * y / 2	((x + 1) * y) / 2 x + ((1 * y) / 2) x+ (1 * (y / 2))
6	x / 2 + y / 2	((x / 2) + y) / 2 (x / 2) + (y / 2)

7	What is totCount after executing the following?
	`numItems = 5;`
	`totCount = 1 + (2 * numItems)  * 4;`
		44
		41

The above question set helps make clear why using parentheses to make order of evaluation explicit is good practice. (It also intentionally violated spacing guidelines to help make the point).

Special operators called ***compound operators*** provide a shorthand way to update a variable, such as userAge += 1 being shorthand for userAge = userAge + 1. Other compound operators include -=, *=, /=, and %=.

P Participation Activity

2.4.6: Compound operators.

#	Question	Your answer
1	numAtoms is initially 7. What is numAtoms after: numAtoms += 5?	
2	numAtoms is initially 7. What is numAtoms after: numAtoms *= 2?	
3	Rewrite the statement using a compound operator, or type: Not possible carCount = carCount / 2;	
4	Rewrite the statement using a compound operator, or type: Not possible numItems = boxCount + 1;	

C Challenge Activity

2.4.1: Enter the output of the integer expressions.

Start

Enter the output of the following program.

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

int main() {
   int x = 1;
   int y = 0;

   y = 2 * (x + 8);

   cout << x << " " << y;

   return 0;
}
```

```
1 18
```

1	2	3	4	5

Check Next

C Challenge Activity

2.4.2: Compute an expression.

Write a statement that computes num1 plus num2, divides by 3, and assigns the result to fi

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

int main() {
   int num1 = 0;
   int num2 = 0;
   int finalResult = 0;

   num1 = 4;
   num2 = 5;

   /* Your solution goes here  */

   cout << "Final result: " << finalResult << endl;

   return 0;
}
```

Run

C Challenge Activity

2.4.3: Compute change.

A cashier distributes change using the maximum number of five dollar bills, followed by on
statement that assigns the number of 1 dollar bills to variable numOnes, given amountToC

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

int main() {
   int amountToChange = 0;
   int numFives = 0;
   int numOnes  = 0;

   amountToChange = 19;
   numFives = amountToChange / 5;

   /* Your solution goes here  */

   cout << "numFives: " << numFives << endl;
   cout << "numOnes: " << numOnes << endl;

   return 0;
}
```

Run

C Challenge Activity

2.4.4: Total cost.

A drink costs 2 dollars. A taco costs 3 dollars. Given the number of each, compute total cos

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

int main() {
   int numDrinks = 0;
   int numTacos  = 0;
   int totalCost = 0;

   numDrinks = 4;
   numTacos  = 6;

   /* Your solution goes here  */

   cout << "Total cost: " << totalCost << endl;

   return 0;
}
```

Run

Section 2.5 - Floating-point numbers (double)

A variable is sometimes needed to store a floating-point number like -1.05 or 0.001. A variable defined as type ***double*** stores a floating-point number.

Construct 2.5.1: Floating-point variable definition with initial value of 0.0.

```
double variableName = 0.0; // Initial value is optional but recommended.
```

A ***floating-point literal*** is a number with a fractional part, even if that fraction is 0, as in 1.0, 0.0, or 99.573. Good practice is to always have a digit before the decimal point, as in 0.5, since .5 might mistakenly be viewed as 5..

Figure 2.5.1: Variables of type double: Travel time example.

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

int main() {
   double milesTravel = 0.0; // User input of miles to travel
   double hoursFly    = 0.0; // Travel hours if flying those miles
   double hoursDrive  = 0.0; // Travel hours if driving those miles

   cout << "Enter number of miles to travel: " << endl;
   cin  >> milesTravel;

   hoursFly   = milesTravel / 500.0; // Plane flys 500 mph
   hoursDrive = milesTravel / 60.0;  // Car drives 60 mph

   cout << milesTravel << " miles would take:" << endl;
   cout << hoursFly    << " hours to fly,"     << endl;
   cout << hoursDrive  << " hours to drive."   << endl;

   return 0;
}
```

```
Enter number
1800
1800 miles wo
3.6 hours to
30 hours to d

...

Enter number
400.5
400.5 miles w
0.801 hours t
6.675 hours t
```

P Participation Activity

2.5.1: Defining and assigning double variables.

All variables are of type double and already-defined unless otherwise noted.

#	Question	Your answer
1	Define a double variable named personHeight and initialize to 0.0.	
2	Compute ballHeight divided by 2.0 and assign the result to ballRadius. Do not use the fraction 1.0 / 2.0; instead, divide ballHeight directly by 2.0.	
3	Multiply ballHeight by the fraction one half, namely (1.0 / 2.0), and assign the result to ballRadius. Use the parentheses around the fraction.	

P Participation Activity

2.5.2: Floating-point literals.

#	Question	Your answer
1	Which statement best defines and initializes the double variable?	double currHumidity = 99%;
		double currHumidity = 99.0;
		double currHumidity = 99;
2	Which statement best assigns to the variable? Both variables are of type double.	cityRainfall = measuredRain - 5;
		cityRainfall = measuredRain - 5.0;
3	Which statement best assigns to the variable? cityRainfall is of type double.	cityRainfall = .97;
		cityRainfall = 0.97;

Scientific notation is useful for representing floating-point numbers that are much greater than or much less than 0, such as 6.02×10^{23}. A floating-point literal using ***scientific notation*** is written using an e preceding the power-of-10 exponent, as in 6.02e23 to represent 6.02×10^{23}. The e stands for exponent. Likewise, 0.001 is 1×10^{-3} so 0.001 can be written as 1.0e-3. For a floating-point literal, good practice is to make the leading digit non-zero.

P Participation Activity

2.5.3: Scientific notation.

#	Question	Your answer
1	Type 1.0e-4 as a floating-point literal but not using scientific notation, with a single digit before and four digits after the decimal point.	
2	Type 7.2e-4 as a floating-point literal but not using scientific notation, with a single digit before and five digits after the decimal point.	
3	Type 540,000,000 as a floating-point literal using scientific notation with a single digit before and after the decimal point.	
4	Type 0.000001 as a floating-point literal using scientific notation with a single digit before and after the decimal point.	
5	Type 623.596 as a floating-point literal using scientific notation with a single digit before and five digits after the decimal point.	

In general, a floating-point variable should be used to represent a quantity that is measured, such as a distance, temperature, volume, weight, etc., whereas an integer variable should be used to represent a quantity that is counted, such as a number of cars, students, cities, minutes, etc. Floating-point is also used when dealing with fractions of countable items, such as the average number of cars per household. Note: Some programmers warn against using floating-point for money, as in 14.53 representing 14 dollars and 53 cents, because money is a countable item (reasons are discussed further in another section). int may be used to represent cents, or to represent dollars when cents are not included as for an annual salary (e.g., 40000 dollars, which are countable).

P Participation Activity

2.5.4: Floating-point versus integer.

Choose the right type for a variable to represent each item.

#	Question	Your answer
1	The number of cars in a parking lot.	double int
2	The current temperature in Celsius.	double int
3	A person's height in centimeters.	double int
4	The number of hairs on a person's head.	double int
5	The average number of kids per household.	double int

A ***floating-point divide-by-zero*** occurs at runtime if a divisor is 0.0. Dividing by zero results in inf or -inf depending on the signs of the operands.

P Participation Activity

2.5.5: Floating-point division.

Determine the result.

#	Question	Your answer
1	13.0 / 3.0	4
		4.333333
		Positive infinity
2	0.0 / 5.0	0.0
		Positive infinity
		Negative infinity
3	12.0 / 0.0	12.0
		Positive infinity
		Negative infinity

C Challenge Activity

2.5.1: Sphere volume.

Given sphereRadius and piVal, compute the volume of a sphere and assign to sphereVolu
which performs integer division.

Volume of sphere = (4.0 / 3.0) π r^3

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

int main() {
   const double piVal = 3.14159;
   double sphereVolume = 0.0;
   double sphereRadius = 0.0;

   sphereRadius = 1.0;

   /* Your solution goes here  */

   cout << "Sphere volume: " << sphereVolume << endl;

   return 0;
}
```

Run

C Challenge Activity

2.5.2: Acceleration of gravity.

Compute the acceleration of gravity for a given distance from the earth's center, distCenter
of gravity is: *(G * M) / (d²)*, where G is the gravitational constant 6.673 x 10^{-11}, M is the ma
earth's center (stored in variable distCenter).

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

int main() {
   const double G       = 6.673e-11;
   const double M       = 5.98e24;
   double accelGravity = 0.0;
   double distCenter   = 0.0;

   distCenter = 6.38e6;

   /* Your solution goes here  */

   cout << "accelGravity: " << accelGravity << endl;

   return 0;
}
```

Run

Section 2.6 - Constant variables

A good practice is to minimize the use of literal numbers in code. One reason is to improve code readability. newPrice = origPrice - 5 is less clear than newPrice = origPrice - priceDiscount. When a variable represents a literal, the variable's value should not be changed in the code. If the programmer precedes the variable definition with the keyword ***const***, then the compiler will report an error if a later statement tries to change that variable's value. An initialized variable whose value cannot change is called a ***constant variable***. A common convention, or good practice, is to name constant variables using upper case letters with words separated by underscores, to make constant variables clearly visible in code.

Figure 2.6.1: Constant variable example: Lightning distance.

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

/*
 * Estimates distance of lightning based on seconds
 * between lightning and thunder
 */

int main() {
   const double SPEED_OF_SOUND   = 761.207; // Miles/hour (sea level)
   const double SECONDS_PER_HOUR = 3600.0;  // Secs/hour
   double secondsBetween = 0.0;
   double timeInHours    = 0.0;
   double distInMiles    = 0.0;

   cout << "Enter seconds between lightning and thunder:"  << endl;
   cin  >> secondsBetween;

   timeInHours = secondsBetween / SECONDS_PER_HOUR;
   distInMiles = SPEED_OF_SOUND * timeInHours;

   cout << "Lightning strike was approximately" << endl;
   cout << distInMiles << " miles away." << endl;

   return 0;
}
```

```
Enter secor
7
Lightning s
1.48012 mil

...

Enter secor
1
Lightning s
0.211446 mi
```

P Participation Activity

2.6.1: Constant variables.

Which of the following statements are valid definitions and uses of a constant integer variable named STEP_SIZE?

#	Question	Your answer
1	`int STEP_SIZE = 5;`	True / False
2	`const int STEP_SIZE = 14;`	True / False
3	`totalStepHeight = numSteps * STEP_SIZE;`	True / False
4	`STEP_SIZE = STEP_SIZE + 1;`	True / False

C Challenge Activity

2.6.1: Using constants in expressions.

Assign shipCostCents with the cost of shipping a package weighing shipWeightPounds. Th
Declare and use a const named CENTS_PER_POUND.

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

int main() {
   int shipWeightPounds = 10;
   int shipCostCents = 0;
   const int FLAT_FEE_CENTS = 75;

   /* Your solution goes here  */

   cout << "Weight(lb): " << shipWeightPounds;
   cout << ", Flat fee(cents): " << FLAT_FEE_CENTS;
   cout << ", Cents per lb: " << CENTS_PER_POUND;
   cout << ", Shipping cost(cents): " << shipCostCents << endl;

   return 0;
}
```

Run

Section 2.7 - Using math functions

Some programs require math operations beyond basic operations like + and *, such as computing a square root or raising a number to a power. Thus, the language comes with a standard ***math library*** that has about 20 math operations available for floating-point values, listed later in this section. As shown below, the programmer first includes the library at the top of a file (highlighted yellow), and then can use math operations (highlighted orange).

Figure 2.7.1: Using a math function from the math library.

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

...

double sideSquare = 0.0;
double areaSquare = 49.0;

sideSquare = sqrt(areaSquare);
```

sqrt is a *function*. A ***function*** is a list of statements that can be executed by referring to the function's name. An input value to a function appears between parentheses and is known as an ***argument***, such as areaSquare above. The function executes and *returns* a new value. In the example above, sqrt(areaSquare) returns 7.0, which is assigned to sideSquare. Invoking a function is a ***function call***.

Some function have multiple arguments. For example, pow(b, e) returns the value of b^e.

Figure 2.7.2: Math function example: Mass growth.

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

int main() {
   double initMass   = 0.0;  // Initial mass of a substance
   double growthRate = 0.0;  // Annual growth rate
   double yearsGrow  = 0.0;  // Years of growth
   double finalMass  = 0.0;  // Final mass after those years

   cout << "Enter initial mass: " << endl;
   cin  >> initMass;

   cout << "Enter growth rate (Ex: 0.05 is 5%/year): " << endl;
   cin  >> growthRate;

   cout << "Enter years of growth: " << endl;
   cin  >> yearsGrow;

   finalMass = initMass * pow(1.0 + growthRate, yearsGrow);
   // Ex: Rate of 0.05 yields initMass * 1.05^yearsGrow

   cout << "Final mass after " << yearsGrow
        << " years is: " << finalMass << endl;

   return 0;
}
```

```
Enter initial mass:
10000
Enter growth rate (Ex: 0.05 is 5%/year):
0.06
Enter years of growth:
20
Final mass after 20 years is: 32071.4

...

Enter initial mass:
10000
Enter growth rate (Ex: 0.05 is 5%/year):
0.40
Enter years of growth:
10
Final mass after 10 years is: 289255
```

P Participation Activity

2.7.1: Calculate Pythagorean theorem.

Select the three statements that calculate the value of x in the following:

- x = square-root-of(y^2 + z^2)

(Note: Calculate y^2 before z^2 for this exercise.)

#	Question	Your answer
1	First statement is:	temp1 = pow(x , 2.0);
		temp1 = pow(z , 3.0);
		temp1 = pow(y , 2.0);
		temp1 = sqrt(y);
2	Second statement is:	temp2 = sqrt(x , 2.0);
		temp2 = pow(z , 2.0);
		temp2 = pow(z);
		temp2 = x + sqrt(temp1 + temp2);
3	Third statement is:	temp2 = sqrt(temp1 + temp2);
		x = pow(temp1 + temp2, 2.0);
		x = sqrt(temp1) + temp2;
		x = sqrt(temp1 + temp2);

Table 2.7.1: Some functions in the standard math library.

Function	Description		Function	Description
pow	Raise to power		***cos***	Cosine
sqrt	Square root		***sin***	Sine
			tan	Tangent
exp	Exponential function		***acos***	Arc cosine
log	Natural logarithm		***asin***	Arc sine
log10	Common logarithm		***atan***	Arc tangent
			atan2	Arc tangent with two parameters
ceil	Round up value		***cosh***	Hyperbolic cosine
fabs	Compute absolute value		***sinh***	Hyperbolic sine
floor	Round down value		***tanh***	Hyperbolic tangent
fmod	Remainder of division			
abs	Compute absolute value		***frexp***	Get significand and exponent
			ldexp	Generate number from significand and exponent
			modf	Break into fractional and integral parts

See http://www.cplusplus.com/reference/clibrary/cmath/ for details.

The c in the library name cmath indicates that the library comes from a library originally available in the C language.

A few additional math functions for integer types are defined in another library called cstdlib, requiring: `#include <cstdlib>` for use. For example, ***abs()*** is the math function for computing the absolute value of an integer.

P Participation Activity

2.7.2: Variable assignments with math functions.

Determine the final value of z. All variables are of type double. Answer in the form 9.0.

#	Question	Your answer

1	`y = 2.3;`
	`z = 3.5;`
	`z = ceil(y);`	

2	`y = 2.3;`
	`z = 3.5;`
	`z = floor(z);`	

3	`y = 3.7;`
	`z = 4.5;`
	`z = pow(floor(z), 2.0);`	

4	`z = 15.75;`
	`z = sqrt(ceil(z));`	

5	`z = fabs(-1.8);`	

Challenge Activity

2.7.1: Coordinate geometry.

Determine the distance between point (x1, y1) and point (x2, y2), and assign the result to p
Distance = SquareRootOf((x2 - x1)^2 + (y2 - y1)^2)
You may declare additional variables.
Ex: For points (1.0, 2.0) and (1.0, 5.0), pointsDistance is 3.0.

```cpp
#include <iostream>
#include <cmath>
using namespace std;

int main() {
   double x1 = 1.0;
   double y1 = 2.0;
   double x2 = 1.0;
   double y2 = 5.0;
   double pointsDistance = 0.0;

   /* Your solution goes here  */

   cout << "Points distance: " << pointsDistance << endl;

   return 0;
}
```

Run

C Challenge Activity

2.7.2: Tree Height.

Simple geometry can compute the height of an object from the object's shadow length and shadowLength. Given the shadow length and angle of elevation, compute the tree height.

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

int main( ) {
   double treeHeight     = 0.0;
   double shadowLength   = 0.0;
   double angleElevation = 0.0;

   angleElevation = 0.11693706; // 0.11693706 radians = 6.7 degrees
   shadowLength   = 17.5;

   /* Your solution goes here  */

   cout << "Tree height: " << treeHeight << endl;

   return 0;
}
```

Run

Section 2.8 - Type conversions

A calculation sometimes must mix integer and floating-point numbers. For example, given that about 50.4% of human births are males, then `0.504 * numBirths` calculates the number of expected males in numBirths births. If numBirths is an int variable (int because the number of births is countable), then the expression combines a floating-point and integer.

A ***type conversion*** is a conversion of one data type to another, such as an int to a double. The compiler automatically performs several common conversions between int and double types, such automatic conversion known as ***implicit conversion***.

- For an arithmetic operator like + or *, if either operand is a double, the other is automatically converted to double, and then a floating-point operation is performed.
- For assignment =, the right side type is converted to the left side type.

int-to-double conversion is straightforward: 25 becomes 25.0.

double-to-int conversion just drops the fraction: 4.9 becomes 4.

Consider the statement `expectedMales = 0.504 * numBirths`, where both variables are int type. if numBirths is 316, the compiler sees "double * int" so automatically converts 316 to 316.0, then computes 0.504 * 316.0 yielding 159.264. The compiler then sees "int = double" so automatically converts 159.264 to 159, and then assigns 159 to expectedMales.

P Participation Activity

2.8.1: Implicit conversions among double and int.

Type the value of the given expression, given int numItems = 5, and double itemWeight = 0.5. For any floating-point answer, give answer to tenths, e.g., 8.0, 6.5, or 0.1.

#	Question	Your answer
1	3.0 / 1.5	
2	3.0 / 2	
3	(numItems + 10) / 2	
4	(numItems + 10) / 2.0	

P Participation Activity

2.8.2: Implicit conversions among double and int with variables.

Type the value stored in the given variable after the assignment statement, given int numItems = 5, and double itemWeight = 0.5. For any floating-point answer, give answer to tenths, e.g., 8.0, 6.5, or 0.1.

#	Question	Your answer
1	someDoubleVar = itemWeight * numItems; (someDoubleVar is type double).	
2	someIntVar = itemWeight * numItems; (someIntVar is type int).	

Because of implicit conversion, statements like `double someDoubleVar = 0;` or `someDoubleVar = 5;` are allowed, but discouraged. Using 0.0 or 5.0 is preferable.

Sometimes a programmers needs to explicitly convert an item's type. The following code undesirably performs integer division rather than floating-point division.

Figure 2.8.1: Code that undesirably performs integer division.

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

int main() {
   int kidsInFamily1 = 3; // Should be int, not double
   int kidsInFamily2 = 4; // (know anyone with 2.3 kids?)
   int numFamilies   = 2; // Should be int, not double

   double avgKidsPerFamily = 0.0; // Expect fraction, so double

   avgKidsPerFamily = (kidsInFamily1 + kidsInFamily2) / numFamilies;

   // Should be 3.5, but is 3 instead
   cout << "Average kids per family: " << avgKidsPerFamily << endl;

   return 0;
}
```

```
Average kids
```

A common error is to accidentally perform integer division when floating-point division was intended.

A programmer can precede an expression with ***static_cast<type>***(expression) to convert the expression's value to the indicated type. For example, if myIntVar is 7, then static_cast<double>(myIntVar) converts int 7 to double 7.0.

Such explicit conversion by the programmer of one type to another is known as ***type casting***.

Figure 2.8.2: Using type casting to obtain floating-point division.

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

int main() {
   int kidsInFamily1 = 3; // Should be int, not double
   int kidsInFamily2 = 4; // (know anyone with 2.3 kids?)
   int numFamilies   = 2; // Should be int, not double

   double avgKidsPerFamily = 0.0; // Expect fraction, so double

   avgKidsPerFamily = static_cast<double>(kidsInFamily1 + kidsInFamily2)
                    / static_cast<double>(numFamilies);

   cout << "Average kids per family: " << avgKidsPerFamily << endl;

   return 0;
}
```

```
Average
```

A common error is to cast the entire result of integer division, rather than the operands, thus not obtaining the desired floating-point division. For example, `static_cast<double>((5 + 10) / 2)` yields 7.0 (integer division yields 7, then converted to 7.0) rather than 7.5.

P Participation Activity

2.8.3: Type casting.

#	Question	Your answer
1	Which yields 2.5?	static_cast<int>(10) / static_cast<int>(4)
		static_cast<double>(10) / static_cast<double>(4)
		static_cast<double>(10 / 4)

C Challenge Activity

2.8.1: Type casting: Computing average kids per family

Compute the average kids per family. Note that the integers should be type cast to doubles

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

int main() {
   int numKidsA = 1;
   int numKidsB = 4;
   int numKidsC = 5;
   int numFamilies = 3;
   double avgKids = 0.0;

   /* Your solution goes here  */

   cout << "Average kids per family: " << avgKids << endl;

   return 0;
}
```

Run

Section 2.9 - Binary

Normally, a programmer can think in terms of base ten numbers. However, a compiler must allocate some finite quantity of bits (e.g., 32 bits) for a variable, and that quantity of bits limits the range of numbers that the variable can represent. Thus, some background on how the quantity of bits influences a variable's number range is helpful.

Because each memory location is composed of bits (0s and 1s), a processor stores a number using base 2, known as a ***binary number***.

For a number in the more familiar base 10, known as a ***decimal number***, each digit must be 0-9 and each digit's place is weighed by increasing powers of 10.

Table 2.9.1: Decimal numbers use weighed powers of 10.

Decimal number with 3 digits	Representation
212	$2*10^2 + 1*10^1 + 2*10^0 =$ $2*100 + 1*10 + 2*1 =$ $200 + 10 + 2 =$ 212

In ***base 2***, each digit must be 0-1 and each digit's place is weighed by increasing powers of 2.

Table 2.9.2: Binary numbers use weighed powers of 2.

Binary number with 4 bits	Representation
1101	$1*2^3 + 1*2^2 + 0*2^1 + 1*2^0 =$ $1*8 + 1*4 + 0*2 + 1*1 =$ $8 + 4 + 0 + 1 =$ 13

The compiler translates decimal numbers into binary numbers before storing the number into a memory location. The compiler would convert the decimal number 212 to the binary number 11010100, meaning 1*128 + 1*64 + 0*32 + 1*16 + 0*8 + 1*4 + 0*2 + 0*1 = 212, and then store that binary number in memory.

P Participation Activity

2.9.1: Understanding binary numbers.

Set each binary digit for the unsigned binary number below to 1 or 0 to obtain the decimal equivalents of 9, then 50, then 212, then 255. Note also that 255 is the largest integer that the 8 bits can represent.

0	0	0	0	0	0	0	0	0 (decimal value)
128	64	32	16	8	4	2	1	
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	

P Participation Activity

2.9.2: Binary numbers.

#	Question	Your answer
1	Convert the binary number 00001111 to a decimal number.	
2	Convert the binary number 10001000 to a decimal number.	
3	Convert the decimal number 17 to an 8-bit binary number.	
4	Convert the decimal number 51 to an 8-bit binary number.	

Section 2.10 - Characters

A variable of ***char*** type can store a single character, like the letter m or the symbol %. A ***character literal*** is surrounded with single quotes, as in 'm' or '%'.

Figure 2.10.1: Simple char example: Arrow.

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

int main() {
   char arrowBody = '-';
   char arrowHead = '>';

   cout << arrowBody << arrowBody << arrowBody << arrowHead << endl;

   arrowBody = 'o';

   cout << arrowBody << arrowBody << arrowBody << arrowHead << endl;

   return 0;
}
```

```
--->
ooo>
```

A common error is to use double quotes rather than single quotes around a character literal, as in `myChar = "x"`, yielding a compiler error. Similarly, a common error is to forget the quotes around a character literal, as in `myChar = x`, usually yielding a compiler error.

P Participation Activity

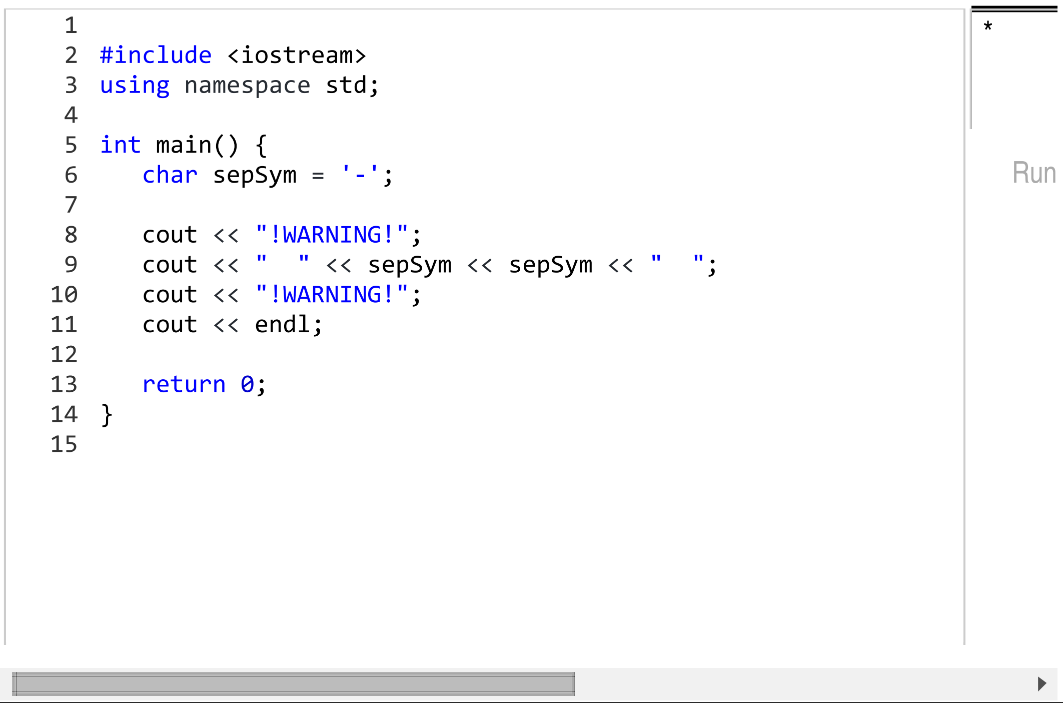
2.10.1: char data type.

#	Question	Your answer
1	In one statement, define a variable named userKey of type char and initialize to the letter a.	

P Participation Activity

2.10.2: char variables.

Modify the program to use a char variable alertSym for the ! symbols surrounding the word WARNING, and test. Then, modify further to have the user input that symbol.



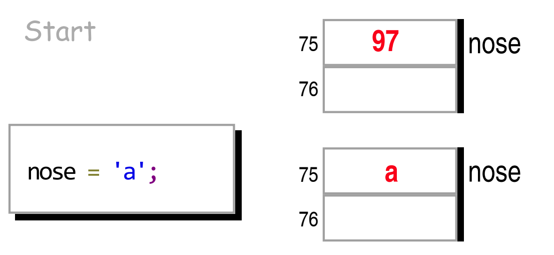
```

#include <iostream>
using namespace std;

int main() {
   char sepSym = '-';

   cout << "!WARNING!";
   cout << "   " << sepSym << sepSym << "   ";
   cout << "!WARNING!";
   cout << endl;

   return 0;
}

```

```
*
```

Under the hood, a char variable stores a number. For example, the letter m is stored as 109. A table showing the standard number used for common characters appears at this section's end. Though stored as a number, the compiler knows to output a char type as the corresponding character.

P Participation Activity

2.10.3: A char is stored as a number, but thought of as a character.



P Participation Activity

2.10.4: Character encodings.

Type a character:

A

ASCII number:

65

ASCII is an early standard for encoding characters as numbers. The following table shows the ASCII encoding as a decimal number (Dec) for common printable characters (for readers who have studied binary numbers, the table shows the binary encoding also). Other characters such as control characters (e.g., a "line feed" character) or extended characters (e.g., the letter "n" with a tilde above it as used in Spanish) are not shown. Sources: Wikipedia: ASCII, http://www.asciitable.com/.

Table 2.10.1: Character encodings as numbers in the ASCII standard.

Binary	Dec	Char	Binary	Dec	Char	Binary	Dec	Char
010 0000	32	space	100 0000	64	@	110 0000	96	`
010 0001	33	!	100 0001	65	A	110 0001	97	a
010 0010	34	"	100 0010	66	B	110 0010	98	b
010 0011	35	#	100 0011	67	C	110 0011	99	c
010 0100	36	$	100 0100	68	D	110 0100	100	d
010 0101	37	%	100 0101	69	E	110 0101	101	e
010 0110	38	&	100 0110	70	F	110 0110	102	f
010 0111	39	'	100 0111	71	G	110 0111	103	g
010 1000	40	(	100 1000	72	H	110 1000	104	h
010 1001	41	)	100 1001	73	I	110 1001	105	i
010 1010	42	*	100 1010	74	J	110 1010	106	j
010 1011	43	+	100 1011	75	K	110 1011	107	k
010 1100	44	,	100 1100	76	L	110 1100	108	l
010 1101	45	-	100 1101	77	M	110 1101	109	m
010 1110	46	.	100 1110	78	N	110 1110	110	n
010 1111	47	/	100 1111	79	O	110 1111	111	o
011 0000	48	0	101 0000	80	P	111 0000	112	p

011 0001	49	1	101 0001	81	Q	111 0001	113	q
011 0010	50	2	101 0010	82	R	111 0010	114	r
011 0011	51	3	101 0011	83	S	111 0011	115	s
011 0100	52	4	101 0100	84	T	111 0100	116	t
011 0101	53	5	101 0101	85	U	111 0101	117	u
011 0110	54	6	101 0110	86	V	111 0110	118	v
011 0111	55	7	101 0111	87	W	111 0111	119	w
011 1000	56	8	101 1000	88	X	111 1000	120	x
011 1001	57	9	101 1001	89	Y	111 1001	121	y
011 1010	58	:	101 1010	90	Z	111 1010	122	z
011 1011	59	;	101 1011	91	[	111 1011	123	{
011 1100	60	<	101 1100	92	\	111 1100	124	|
011 1101	61	=	101 1101	93	]	111 1101	125	}
011 1110	62	>	101 1110	94	^	111 1110	126	~
011 1111	63	?	101 1111	95	_			

In addition to visible characters like Z, $, or 5, the encoding includes numbers for several special characters. Ex: A newline character is encoded as 10. Because no visible character exists for a newline, the language uses an escape sequence. An ***escape sequence*** is a two-character sequence starting with \ that represents a special character. Ex: '\n' represents a newline character. Escape sequences also enable representing characters like ', ", or \. Ex: myChar = '\'' assigns myChar with a single-quote character. myChar = '\\' assigns myChar with \ (just '\' would yield a compiler error, since \' is the escape sequence for ', and then a closing ' is missing).

Table 2.10.2: Common escape sequences.

Escape sequence	Char
\n	newline
\t	tab
\'	single quote
\"	double quote
\\	backslash

P Participation Activity

2.10.5: Character encoding.

#	Question	Your answer
1	The statement `char keyPressed = 'R'` stores what decimal number in the memory location for keyPressed?	

C Challenge Activity

2.10.1: Printing a message with ints and chars.

Print a message telling a user to press the letterToQuit key numPresses times to quit. End

```
Press the q key 2 times to quit.
```

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

int main() {
   char letterToQuit = '?';
   int  numPresses    = 0;

   /* Your solution goes here  */

   return 0;
}
```

Run

C Challenge Activity

2.10.2: Singing the alphabet.

Define a character variable letterStart. Read the character from the user, print that letter ar
'a':

```
ab
```

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

int main() {

   /* Your solution goes here  */

   return 0;
}
```

Run

Section 2.11 - String basics

Some variables should store a sequence of characters like the name Julia. A sequence of characters is called a ***string***. A string literal uses double quotes as in "Julia". Various characters may be included, such as letters, numbers, spaces, symbols like $, etc., as in "Hello ... Julia!!".

P Participation Activity

2.11.1: A string is stored as a sequence of characters in memory.

Type a string below to see how a string is stored as a sequence of characters in memory (in this case, the string happens to be allocated to memory locations 501 to 506).

Type a string (up to 6 characters): Julia

Memory

501	J
502	u
503	l
504	i
505	a
506	

A string data type isn't built into C++ as are char, int, or double. But a string data type is available in the standard library and can be used after adding: `#include <string>`. A programmer can then define a string variable as: `string firstName;`.

Figure 2.11.1: Strings example: Word game.

```
#include <iostream>
#include <string>     // Supports use of "string" data type
using namespace std;

/* A game inspired by "Mad Libs" where user enters nouns,
 * verbs, etc., and then a story using those words is output.
 */

int main() {
   string wordRelative;
   string wordFood;
   string wordAdjective;
   string wordTimePeriod;

   // Get user's words
   cout << "Type input without spaces." << endl;

   cout << "Enter a kind of relative: " << endl;
   cin  >> wordRelative;

   cout << "Enter a kind of food: " << endl;
   cin  >> wordFood;

   cout << "Enter an adjective: "   << endl;
   cin  >> wordAdjective;

   cout << "Enter a time period: "  << endl;
   cin  >> wordTimePeriod;

   // Tell the story
   cout << endl;
   cout << "My " << wordRelative << " says eating " << wordFood << endl;
   cout << "will make me more " << wordAdjective << "," << endl;
   cout << "so now I eat it every " << wordTimePeriod << "." << endl;

   return 0;
}
```

```
Provide
Enter a
mother
Enter a
apples
Enter ar
loud
Enter a
week

My mothe
will mak
so now I
```

P Participation Activity

2.11.2: Strings.

#	Question	Your answer
1	Define a string named firstName.	
2	Print a string named firstName.	
3	Read a string from input into firstName.	

A programmer can initialize a string variable during definition: `string firstMonth = "January";`. Otherwise, a string variable is automatically initialized to an empty string "".

P Participation Activity

2.11.3: String initialization.

#	Question	Your answer
1	Define a string named smallestPlanet, initialized to "Mercury", using the above syntax.	

`cin >> stringVar` gets the next input string only up to the next input space, tab, or newline character, known as whitespace characters. A ***whitespace character*** is a character used to print spaces in text, and includes spaces, tabs, and newline characters. So following the user typing `Betty Sue(ENTER)`, cin will only store Betty in stringVar. Sue will be the next input string. In contrast, the function ***getline***(cin, stringVar) reads all user text on the input line, up to the newline character resulting from the user pressing ENTER, into stringVar.

Figure 2.11.2: Reading an input string containing spaces using getline.

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

int main() {
   string firstName;
   string lastName;

   cout << "Enter first name:" << endl;
   getline(cin, firstName); // Gets entire line up to ENTER

   cout << "Enter last name:" << endl;
   getline(cin, lastName); // Gets entire line up to ENTER

   cout << endl;
   cout << "Welcome " << firstName << " " << lastName << "!" << endl;
   cout << "May I call you " << firstName << "?" << endl;

   return 0;
}
```

```
Enter first
Betty Sue
Enter last
McKay

Welcome Bet
May I call
```

(An interesting poem about Sue McKay on YouTube (4 min)).

P Participation Activity

2.11.4: Input string with spaces.

(ENTER) means the user presses the enter/return key.

#	Question	Your answer
1	Asked to enter a fruit name, the user types: `Fuji Apple (ENTER).` What does `cin >> fruitName` store in fruitName?	

2	Given:
	
	`cout << "Enter fruit name:" << endl;`
	`cin  >> fruitName;`
	`cout << "Enter fruit color: " << endl;`
	`cin  >> fruitColor;`
	
	The user will type *Fuji Apple (ENTER)* for the fruit name and *red (ENTER)* for the fruit color. What is stored in fruitColor?	

3	Using getline(), type a statement that reads an entire user-entered line of text into string userStr.	

P Participation Activity

2.11.5: Reading string input.

The following program is part of a larger application to get a user's mailing address. Run the program and observe the output. Update the program to store the entire mailing address in `userAddress`.

```

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

int main() {
   string userAddress;

   cout << "Enter street address: ";
   cin >> userAddress;

   cout <<endl << "Street address is: " << userAddress << endl

   return 0;
}

```

1600 P

Run

A programmer can assign a value to a string like other types, e.g., str1 = "Hello", or str1 = str2. The string type automatically reallocates memory for str1 if the assigned string is larger or smaller, and then copies the characters into str1.

Figure 2.11.3: Assigning a value to a string.

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

int main() {
   string userNoun1;
   string userVerb;
   string userNoun2;
   string sentenceSubject;
   string sentenceObject;

   cout << "Enter a noun: ";
   cin  >> userNoun1;
   cout << "Enter a verb: ";
   cin  >> userVerb;
   cout << "Enter a noun: ";
   cin  >> userNoun2;

   sentenceSubject = userNoun1;
   sentenceObject  = userNoun2;
   cout << sentenceSubject << " ";
   cout << userVerb        << " ";
   cout << sentenceObject  << "." << endl;

   sentenceSubject = userNoun2;
   sentenceObject  = userNoun1;
   cout << sentenceSubject << " ";
   cout << userVerb        << " ";
   cout << sentenceObject  << "." << endl;

   return 0;
}
```

```
Enter a noun: mice
Enter a verb: eat
Enter a noun: cheese
mice eat cheese.
cheese eat mice.
```

P Participation Activity

2.11.6: Assigning a value to a string variable.

str1 and str2 are string variables.

#	Question	Your answer
1	Write a statement that assigns "miles" to str1.	
2	str1 is initially "Hello", str2 is "Hi". After str1 = str2, what is str1? Omit the quotes.	
3	str1 is initially "Hello", str2 is "Hi". After str1 = str2 and then str2 = "Bye", what is str1? Omit the quotes.	

C Challenge Activity

2.11.1: Reading and printing a string.

A user types a word and a number. Read them into the provided variables. Then print: wor

```
Amy_5
```

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

int main() {
   string userWord;
   int userNum = 0;

   /* Your solution goes here  */

   return 0;
}
```

Run

Section 2.12 - Integer overflow

An integer variable cannot store a number larger than the maximum supported by the variable's data type. An ***overflow*** occurs when the value being assigned to a variable is greater than the maximum value the variable can store.

A common error is to try to store a value greater than about 2 billion into an int variable. For example, the decimal number 4,294,967,297 requires 33 bits in binary, namely 100000000000000000000000000000001 (we chose the decimal number for easy binary viewing). Trying to assign that number into an int results in overflow. The 33rd bit is lost and only the lower 32 bits are stored, namely 00000000000000000000000000000001, which is decimal number 1.

P Participation Activity

2.12.1: Overflow error.

Defining the variable of type *long long*, (described in another section) which uses at least 64 bits, would solve the above problem. But even that variable could overflow if assigned a large enough value.

Most compilers detect when a statement assigns to a variable a literal constant so large as to cause overflow. The compiler may not report a syntax error (the syntax is correct), but may output a ***compiler warning*** message that indicates a potential problem. A GNU compiler outputs the message "warning: overflow in implicit constant conversion", and a Microsoft compiler outputs "warning: '=': truncation of constant value". Generally, good practice is for a programmer to not ignore compiler warnings.

A common source of overflow involves intermediate calculations. Given int variables num1, num2, num3 each with values near 1 billion, (num1 + num2 + num3) / 3 will encounter overflow in the numerator, which will reach about 3 billion (max int is around 2 billion), even though the final result after dividing by 3 would have been only 1 billion. Dividing earlier can sometimes solve the problem, as in (num1 / 3) + (num2 / 3) + (num3 / 3), but programmers should pay careful attention to possible implicit type conversions.

Participation Activity

2.12.2: long long variables.

Run the program and observe the output is as expected. Replicate the multiplication and printing three more times, and observe incorrect output due to overflow. Change num's type to *long long*, and observe the corrected output.

```

#include <iostream>
using namespace std;

int main() {
   int num = 1000;

   num = num * 100;
   cout << "num: " << num << endl;

   num = num * 100;
   cout << "num: " << num << endl;

   num = num * 100;
   cout << "num: " << num << endl;

   return 0;
}

```

Run

P Participation Activity

2.12.3: Overflow.

Assume all variables below are defined as int, which uses 32 bits.

#	Question	Your answer
1	Overflow can occur at any point in the program, and not only at a variable's initialization.	Yes No
2	Will x = 1234567890 cause overflow?	Yes No
3	Will x = 9999999999 cause overflow?	Yes No
4	Will x = 4000000000 cause overflow?	Yes No

5	Will these assignments cause overflow?
	x = 1000;
	y = 1000;
	z = x * y;
		Yes
		No

6	Will these assignments cause overflow?
	x = 1000;
	y = 1000;
	z = x * x;
	z = z * y * y;
		Yes
		No

Section 2.13 - Numeric data types

int and double are the most common numeric data types. However, several other numeric types exist. The following table summarizes available integer numeric data types.

The size of integer numeric data types can vary between compilers, for reasons beyond our scope. The following table lists the sizes for numeric integer data types used in this material along with the minimum size for those data types defined by the language standard.

Table 2.13.1: Integer numeric data types.

Definition	Size	Supported number range	Standard-defined minimum size
char myVar;	8 bits	-128 to 127	8 bits
short myVar;	16 bits	-32,768 to 32,767	16 bits
long myVar;	32 bits	-2,147,483,648 to 2,147,483,647	32 bits
long long myVar;	64 bits	-9,223,372,036,854,775,808 to 9,223,372,036,854,775,807	64 bits
int myVar;	32 bits	-2,147,483,648 to 2,147,483,647	*16 bits*

int is the most commonly used integer type. int

long long is used for integers expected to exceed about 2 billion. That is not a typo; the word appears twice.

In case the reader is wondering, the language does not have a simple way to print numbers with commas. So if x is 8000000, printing 8,000,000 is not trivial.

A common error made by a program's user is to input the wrong type, such as inputting a string like twenty (rather than 20) when the input statement was `cin >> myInt;` where myInt is an int, which can cause strange program behavior.

short is rarely used. One situation is to save memory when storing many (e.g., tens of thousands) of smaller numbers, which might occur for arrays (another section). Another situation is in *embedded* computing systems having a tiny processor with little memory, as in a hearing aid or TV remote control. Similarly, char, while technically a number, is rarely used to directly store a number, except as noted for short.

P Participation Activity

2.13.1: Integer types.

Indicate whether each is a good variable definition for the stated purpose, assuming int is usually used for integers, and long long is only used when absolutely necessary.

#	Question	Your answer
1	The number of days of school per year: `int numDaysSchoolYear;`	True False
2	The number of days in a human's lifetime. `int numDaysLife;`	True False
3	The number of years of the earth's existence. `int numYearsEarth;`	True False
4	The number of human heartbeats in one year, assuming 100 beats/minute. `long long numHeartBeats;`	True False

The following table summarizes available floating-point numeric types.

Table 2.13.2: Floating-point numeric data types.

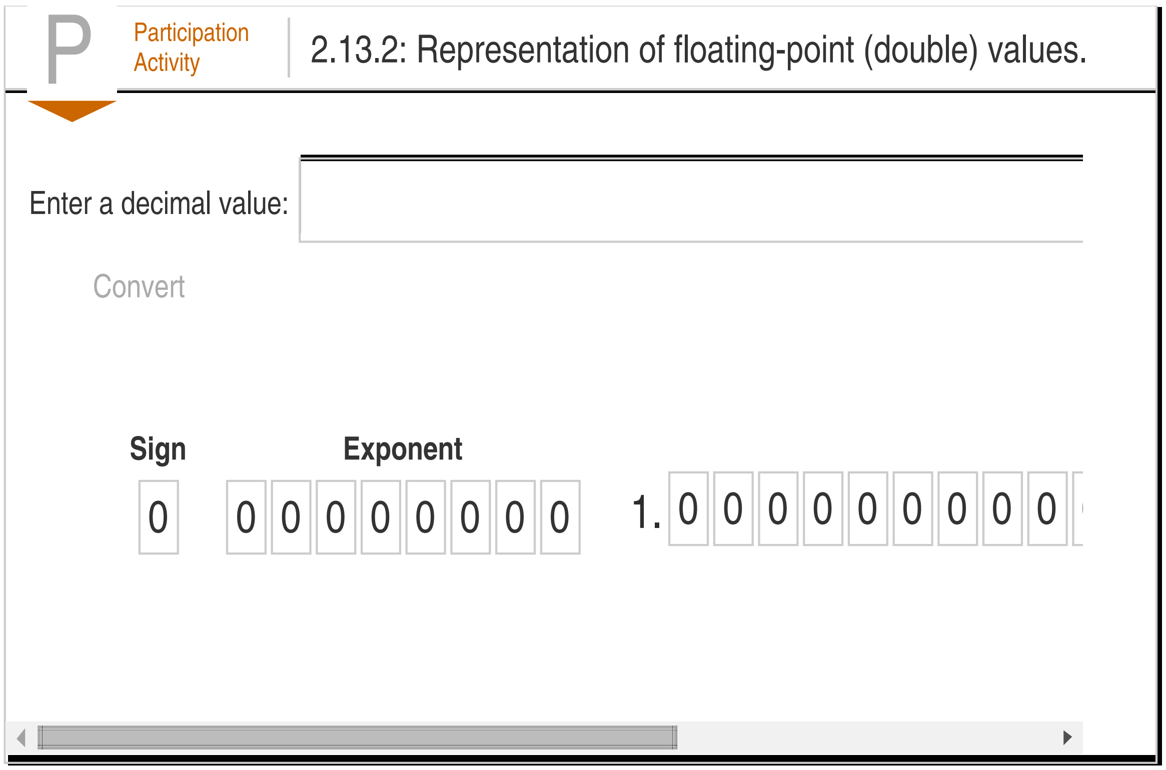
Definition	Size	Supported number range
float x;	32 bits	$-3.4\text{x}10^{38}$ to $3.4*10^{38}$
double x;	64 bits	$-1.7\text{x}10^{308}$ to $1.7*10^{308}$

The compiler uses one bit for sign, some bits for the mantissa, and some for the exponent. Details are beyond our scope. The language (unfortunately) does not actually define the number of bits for float and double types, but the above sizes are very common.

float is typically only used in memory-saving situations, as discussed above for short.

Due to the fixed sizes of the internal representations, the mantissa (e.g, the 6.02 in 6.02e23) is limited to about 7 significant digits for float and about 16 significant digits for double. So for a variable defined as double pi, the assignment pi = 3.14159265 is OK, but pi = 3.14159265358979323846 will be truncated.

A variable cannot store a value larger than the maximum supported by the variable's data type. An ***overflow*** occurs when the value being assigned to a variable is greater than the maximum value the variable can store. Overflow with floating-point results in infinity. Overflow with integer is discussed elsewhere.



2.13.2: Representation of floating-point (double) values.

Enter a decimal value:

Sign: 0

Exponent: 0 0 0 0 0 0 0 0

1. 0 0 0 0 0 0 0 0 0

On some processors, especially low-cost processors intended for "embedded" computing, like systems in an automobile or medical device, floating-point calculations may run slower than integer calculations, such as 100 times slower. Floating-point types are typically only used when really necessary. On more powerful processors like those in desktops, servers, smartphones, etc., special floating-point hardware nearly or entirely eliminates the speed difference.

Floating-point numbers are sometimes used when an integer exceeds the range of the largest integer type.

P Participation Activity | 2.13.3: Floating-point numeric types.

#	Question	Your answer
1	float is the most commonly-used floating-point type.	True False
2	int and double types are limited to about 16 digits.	True False

(*int) Unfortunately, int's size is the processor's "natural" size, and not necessarily 32 bits. Fortunately, nearly every compiler allocates at least 32 bits for int.

Section 2.14 - Unsigned

Sometimes a programmer knows that a variable's numbers will always be positive (0 or greater), such as when the variable stores a person's age or weight. The programmer can prepend the word "unsigned" to inform the compiler that the integers will always be positive. Because the integer's sign needs not be stored, the integer range reaches slightly higher numbers, as follows:

Table 2.14.1: Unsigned integer data types.

Definition	Size	Supported number range	Standard-defined minimum size
unsigned char myVar;	8 bits	0 to 255	8 bits
unsigned short myVar;	16 bits	0 to 65,535	16 bits
unsigned long myVar;	32 bits	0 to 4,294,967,295	32 bits
unsigned long long myVar;	64 bits	0 to 184,467,440,737,095,551,615	64 bits
unsigned int myVar;	32 bits	0 to 4,294,967,295	*16 bits*

Signed numbers use the leftmost bit to store a number's sign, and thus the largest magnitude of a positive or negative integer is half the magnitude for an unsigned integer. Signed numbers actually use a more complicated representation called two's complement, but that's beyond our scope.

The following example demonstrates the use of unsigned long and unsigned long long variables to convert memory size.

Figure 2.14.1: Unsigned variables example: Memory size converter.

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

int main() {
   unsigned long memSizeGB          = 0;
   unsigned long long memSizeBytes = 0;
   unsigned long long memSizeBits  = 0;

   cout << "Enter memory size in GBs: ";
   cin >> memSizeGB;

   // 1 Gbyte = 1024 Mbytes, 1 Mbyte = 1024 Kbytes, 1 Kbyte = 1024 bytes
   memSizeBytes = memSizeGB * (1024 * 1024 * 1024);
   // 1 byte = 8 bits
   memSizeBits = memSizeBytes * 8;

   cout << "Memory size in bytes : " << memSizeBytes << endl;
   cout << "Memory size in bits : " << memSizeBits << endl;

   return 0;
}
```

```
Enter me
Memory s
Memory s

...

Enter me
Memory s
Memory s
```

P Participation Activity

2.14.1: Unsigned variables.

#	Question	Your answer
1	In one statement, define a 64-bit unsigned integer variable numMolecules and initialize to 0.	
2	In one statement, define a 16-bit unsigned integer variable named numAtoms and initialize to 0.	
3	Initialize numAtoms to the smallest valid unsigned value.	`unsigned short numAtoms =`

Section 2.15 - Random numbers

Some programs need to use a random number. For example, a program might serve as an electronic dice roller, generating random numbers between 1 and 6. The following example demonstrates how to generate four random numbers between 1 and 6. The program's relevant parts are explained further below.

Figure 2.15.1: Random numbers: Four dice rolls.

```
1   #include <iostream>
2   #include <cstdlib>     // Enables use of rand()
3   #include <ctime>       // Enables use of time()
4   using namespace std;
5
6   int main() {
7      srand(time(0));     // "Seeds" the random number generator
8
9      cout << "Four rolls of a dice..." << endl;
10
11     // rand() % 6 yields 0, 1, 2, 3, 4, or 5
12     // so + 1 makes that 1, 2, 3, 4, 5, or 6
13     cout << ((rand() % 6) + 1) << endl;
14     cout << ((rand() % 6) + 1) << endl;
15     cout << ((rand() % 6) + 1) << endl;
16     cout << ((rand() % 6) + 1) << endl;
17
18     return 0;
19  }
```

```
Four rolls of
5
6
2
5

...

Four rolls of
2
3
2
4
```

Lines 2 and 3 enable use of the function rand() and time(), respectively. Functions are described elsewhere; here, the programmer can just copy the given code to get random numbers. Line 7 *seeds* the random number generator, described below.

After the above setup, line 13 invokes rand(). ***rand()*** returns an integer in the range 0 to RAND_MAX, defined in stdlib and whose value is machine-dependent but usually 32767. The % 6 converts that integer to a value between 0 and 5. Line 13 adds 1 to obtain a number between 1 and 6. Lines 14, 15, and 16 follow similarly.

P Participation Activity

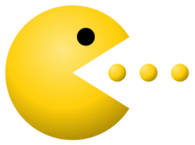
2.15.1: Random numbers.

randGen already exists.

#	Question	Your answer
1	If program is executing and rand() % 10 evaluates to 4, what will the *next* rand() % 10 return?	7
		Unknown
2	What is the smallest *possible* value returned by rand() % 10?	0
		1
		10
		Unknown
3	What is the largest *possible* value returned by rand() % 10?	10
		9
		11
4	Which generates a random number in the range 18..30?	rand() % 30
		rand() % 31
		rand() % (30 - 18)
		(rand() % (30 - 18)) + 18
		(rand() % (30 - 18 + 1)) + 18

Because an important part of testing or debugging a program is being able to have the program run exactly the same across multiple runs, most programming languages use a pseudo-random number generation approach. A ***pseudo-random number generator*** produces a *specific* sequence of numbers based on a seed number, that sequence seeming random but always being the same for a given seed. For example, a program that prints four random numbers and that seeds a random number generator with a seed of 3 might then print 99, 4, 55, and 7. Running with a seed of 8 might yield 42, 0, 22, 9. Running again with 3 will yield 99, 4, 55, and 7 again—guaranteed.

Early video games used a constant seed for "random" features, enabling players to breeze through a level by learning and then repeating the same winning moves.



srand(num) seeds the pseudo-random number generator used by rand(). The s stands for seed. num should be a non-negative integer. A program that should behave identically on every run can use a constant seed as in srand(0). A program whose behavior should change on each run itself needs a random number for the seed; a common way to get such a "random" number is to use the current time, as in srand((int)time(0)) (the details of which we don't describe here).

Having seen the current time's use as a random seed, you might wonder why a program can't just use a number based on the current time as a random number—why bother with a pseudo-random number generator at all? That's certainly possible, but then a program's run could never be identically reproduced. By using a pseudo-random number generator, a programmer can set the seed to a constant value during testing or debugging.

P Participation Activity

2.15.2: Seeding a pseudo-random number generator.

#	Question	Your answer
1	A dice-rolling program has a statement that seeds a pseudo-random number generator with the constant value 99. The program is run and prints 4, 3, 6, 0. An hour later, the program is run again. What is the first number printed? Type a number or "Unknown" if the solution is unknown.	
2	A dice-rolling program's pseudo-random number generator is seeded with a number based on the current time. The program is run and prints 3, 2, 1, 6. An hour later, the program is run again. What is the first number printed? Type a number or "Unknown" if the solution is unknown.	

C Challenge Activity

2.15.1: rand function: Seed and then get random numbers

Type a statement using srand() to seed random number generation using variable seedVa
between 0 and 9. End with a newline. Ex:

```
5
7
```

Note: For this activity, using one statement may yield different output (due to the compiler c

```
#include <iostream>
#include <cstdlib>   // Enables use of rand()
#include <ctime>     // Enables use of time()
using namespace std;

int main() {
   int seedVal = 0;

   /* Your solution goes here  */

   return 0;
}
```

Run

C Challenge Activity

2.15.2: Fixed range of random numbers.

Type **two statements** that use rand() to print 2 random integers between (and including) 1

```
101
133
```

Note: For this activity, using one statement may yield different output (due to the compiler (

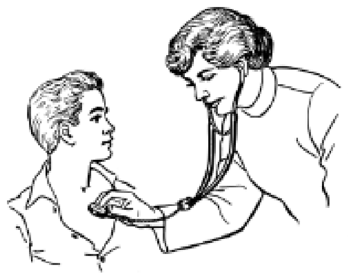
```
#include <iostream>
#include <cstdlib>   // Enables use of rand()
#include <ctime>     // Enables use of time()
using namespace std;

int main() {
   int seedVal = 0;

   seedVal = 4;
   srand(seedVal);

   /* Your solution goes here  */

   return 0;
}
```

Run

Section 2.16 - Debugging

Debugging is the process of determining and fixing the cause of a problem in a computer program. ***Troubleshooting*** is another word for debugging. Far from being an occasional nuisance, debugging is a core programmer task, like diagnosing is a core medical doctor task. Skill in carrying out a methodical debugging process can improve a programmer's productivity.

Figure 2.16.1: A methodical debugging process.



- *Predict a possible cause* of the problem
- *Conduct a test* to validate that cause
- Repeat

A common error among new programmers is to try to debug without a methodical process, instead staring at the program, or making random changes to see if the output is improved.

Consider a program that, given a circle's circumference, computes the circle's area. Below, the output area is clearly too large. In particular, if circumference is 10, then radius is 10 / 2 * PI_VAL, so about 1.6. The area is then PI_VAL * 1.6 * 1.6, or about 8, but the program outputs about 775.

Figure 2.16.2: Circle area program: Problem detected.

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

int main() {
   double circleRadius        = 0.0;
   double circleCircumference = 0.0;
   double circleArea          = 0.0;
   const double PI_VAL        = 3.14159265;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

   circleRadius = circleCircumference / 2 * PI_VAL;
   circleArea = PI_VAL * circleRadius * circleRadius;

   cout << "Circle area is: " << circleArea << endl;

   return 0;
}
```

```
Enter circumference: 10
Circle area is: 775.157
```

First, a programmer may predict that the problem is a bad output statement. This prediction can be tested by adding the statement `area = 999;`. The output statement is OK, and the predicted problem is invalidated. Note that a temporary statement commonly has a "FIXME" comment to remind the programmer to delete this statement.

Figure 2.16.3: Circle area program: Predict problem is bad output.

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

int main() {
   double circleRadius        = 0.0;
   double circleCircumference = 0.0;
   double circleArea          = 0.0;
   const double PI_VAL        = 3.14159265;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

   circleRadius = circleCircumference / 2 * PI_VAL;
   circleArea = PI_VAL * circleRadius * circleRadius;

   circleArea = 999; // FIXME delete
   cout << "Circle area is: " << circleArea << endl;

   return 0;
}
```

```
Enter circumference: 0
Circle area is: 999
```

Next, the programmer predicts the problem is a bad area computation. This prediction is tested by assigning the value 0.5 to radius and checking to see if the output is 0.7855 (which was computed by hand). The area computation is OK, and the predicted problem is invalidated. Note that a temporary statement is commonly left-aligned to make clear it is temporary.

Figure 2.16.4: Circle area program: Predict problem is bad area computation.

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

int main() {
   double circleRadius        = 0.0;
   double circleCircumference = 0.0;
   double circleArea          = 0.0;
   const double PI_VAL        = 3.14159265;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

   circleRadius = circleCircumference / 2 * PI_VAL;

circleRadius = 0.5; // FIXME delete
   circleArea = PI_VAL * circleRadius * circleRadius;

   cout << "Circle area is: " << circleArea << endl;

   return 0;
}
```

```
Enter circumference: 0
Circle area is: 0.785398
```

The programmer then predicts the problem is a bad radius computation. This prediction is tested by assigning PI_VAL to the circumference, and checking to see if the radius is 0.5. The radius computation fails, and the prediction is likely validated. Note that unused code was temporarily commented out.

Figure 2.16.5: Circle area program: Predict problem is bad radius computation.

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

int main() {
   double circleRadius        = 0.0;
   double circleCircumference = 0.0;
   double circleArea          = 0.0;
   const double PI_VAL        = 3.14159265;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

circleCircumference = PI_VAL;                // FIXME delete
   circleRadius = circleCircumference / 2 * PI_VAL;
cout << "Radius: " << circleRadius << endl; // FIXME delete

   /*
    circleArea = PI_VAL * circleRadius * circleRadius;

    cout << "Circle area is: " << circleArea << endl;
    */

   return 0;
}
```

```
Enter circumference:
Radius: 4.9348
```

The last test seems to validate that the problem is a bad radius computation. The programmer visually examines the expression for a circle's radius given the circumference, which looks fine at first glance. However, the programmer notices that `radius = circumference / 2 * PI_VAL;` should have been `radius = circumference / (2 * PI_VAL);`. The parentheses around the product in the denominator are necessary and represent the desired order of operations. Changing to `radius = circumference / (2 * PI_VAL);` solves the problem.

The above example illustrates several common techniques used while testing to validate a predicted problem:

- Manually set a variable to a value.
- Insert print statements to observe variable values.
- Comment out unused code.
- Visually inspect the code (not every test requires modifying/running the code).

Statements inserted for debugging must be created and removed with care. A common error is to forget to remove a debug statement, such as a temporary statement that manually sets a variable to a value. Left-aligning such a statement and/or including a FIXME comment can help the programmer remember. Another common error is to use /* */ to comment out code that itself contains /* */ characters. The first */ ends the comment before intended, which usually yields a syntax error when the second */ is reached or sooner.

The predicted problem is commonly vague, such as "Something is wrong with the input values." Conducting a general test (like printing all input values) may give the programmer new ideas as to a more-specific predicted problems. The process is highly iterative—new tests may lead to new predicted problems. A programmer typically has a few initial predictions, and tests the most likely ones first.

P Participation Activity

2.16.1: Debugging using a repeated two-step process.

Use the above repeating two-step process (predict problem, test to validate) to find the problem in the following code.

```

#include <iostream>
using namespace std;

int main() {
   int sideLength = 0;
   int cubeVolume = 0;

   cout << "Enter cube's side length: " << endl;
   cin >> sideLength;

   cubeVolume = sideLength * sideLength * sideLength;

   cout << "Cube's volume is: " << cubeVolume << endl;

   return 0;
}

```

```
10000
```

Run

P Participation Activity

2.16.2: Debugging.

Answer based on the above discussion.

#	Question	Your answer
1	The first step in debugging is to make random changes to the code and see what happens.	True False
2	A common predicted-problem testing approach is to insert print statements.	True False
3	Variables in temporary statements can be written in uppercase, as in MYVAR = 999, to remind the programmer to remove them.	True False
4	A programmer lists all possible predicted problems first, then runs tests to validate each.	True False
5	Most beginning programmers naturally follow a methodical process.	True False
6	A program's output should be positive and usually is, but in some instances the output becomes negative. Overflow is a good prediction of the problem.	True False

Section 2.17 - Style guidelines

Each programming team, whether a company or a classroom, may have its own style for writing code, sometimes called a ***style guide***. Below is the style guide followed by most code in this material. That style is not necessarily better than any other style. The key is to be consistent in style so that code within a team is easily understandable and maintainable.

You may not have learned all of the constructs discussed below; you may wish to revisit this section after covering new constructs.

Table 2.17.1: Sample style guide.

Sample guidelines, used in this material	Yes	No (for our sample style)
Whitespace		

Each statement usually appears on its own line.	`x = 25;`
	`y = x + 1;`
		`x = 25;   y = x + 1;`
		`if (x == 5) { y = 14;`

A blank line can separate conceptually distinct groups of statements, but related statements usually have no blank lines between them.	`x = 25;`
	`y = x + 1;`
		`x = 25;`
		`                // No`
		`y = x + 1;`

Most items are separated by one space (and not less or more). No space precedes an ending semicolon.	`C = 25;`
	`F = ((9 * C) / 5) + 32;`
	`F = F / 2;`
		`C=25; // No`
		`F = ((9*C)/5) + 32; /`
		`F = F / 2 ; // No`

Sub-statements are indented 3 spaces from parent statement. Tabs are not used as they may behave inconsistently if code is copied to different editors. (Auto-tabbing may need to be disabled in some source code editors).	`if (a < b) {`
	`   x = 25;`
	`   y = x + 1;`
	`}`
		`if (a < b) {`
		`        x = 25;     //`
		`        y = x + 1; //`
		`}`
		`if (a < b) {`
		` x = 25; // No`
		`}`

Braces		

For branches, loops, functions, or classes, opening brace appears at end of the item's line. Closing brace appears under item's start.	`if (a < b) {`
	`   // Called "K&R" style`
	`}`
	`while (x < y) {`
	`   // K&R style`
	`}`
		`if (a < b)`
		`{`
		`   // Also popular, bu`
		`}`

For if-else, the else appears on its own line	`if (a < b) {`
	`   ...`
	`}`
	`else {`
	`   // "Stroustrup" style,  modified K&R`
	`}`
		`if (a < b)`
		`{`
		`   ...`
		`} else {`
		`   // Original K&R sty`
		`}`

Braces always used even if only one sub-statement	`if (a < b) {`
	`   x = 25;`
	`}`
		`if (a < b)`
		`   x = 25;  // No, ca`

Naming		

Variable/parameter names are camelCase, starting with lowercase	`int numItems;`	`int NumItems;   // No`
		`int num_items;  // Co`

Variable/parameter names are descriptive, use at least two words (if possible, to reduce conflicts), and avoid abbreviations unless widely-known like "num". Single-letter variables are rare; exceptions for loop indices (i, j), or math items like point coordinates (x, y).	`int numBoxes;`
	`char userKey;`
		`int boxes;    // No`
		`int b;        // No`
		`char k;       // No`
		`char usrKey;  // No`

Constants use upper case and underscores (and at least two words)	`const int MAXIMUM_WEIGHT = 300;`	`const int MAXIMUMWEIG`
		`const int maximumWeig`
		`const int MAXIMUM = 3`

Variables usually defined early (not within code), and initialized to be	`int i = 0;`
	`char userKey = '-';`
		`int i;         // No`
		`char userKey;  // No`
		
		`userKey = 'c';`

safe (if practical).		`int j;          // No`

Function names are CamelCase with uppercase first.	`PrintHello()`	`printHello()   // No`
		`print_hello()  // No`

Miscellaneous		
Lines of code are typically less than 100 characters wide.	Code is more easily readable when lines are kept short. One long line can usually be broken up into several smaller ones.	

K&R style for braces and indents is named after C language creators Kernighan and Ritchie. ***Stroustrup style*** for braces and indents is named after C++ language creator Bjarne Stroustrup. The above are merely example guidelines.

Exploring further:

- More on indent styles from Wikipedia.org
- Google's C++ Style Guide

Section 2.18 - C++ example: Salary calculation with variables

Using variables in expressions, rather than numbers like 40, makes a program more general and makes expressions more meaningful when read too.

P Participation Activity

2.18.1: Calculate salary: Generalize a program with variables and input.

The following program uses a variable workHoursPerWeek rather than directly using 40 in the salary calculation expression.

1. Run the program, observe the output. Change 40 to 35 (France's work week), and run again.
2. Generalize the program further by using a variable workWeeksPerYear. Run the program. Change 50 to 52, and run again.
3. Introduce a variable monthlySalary, used similarly to annualSalary, to

further improve program readability.

Reset

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

int main() {
   int hourlyWage       = 20;
   int workHoursPerWeek = 40;
   // FIXME: Define and initialize variable workWeeksPerYear, then r
   int annualSalary     = 0;

   annualSalary = hourlyWage * workHoursPerWeek * 50;
   cout << "Annual salary is: ";
   cout << annualSalary << endl;

   cout << "Monthly salary is: ";
   cout << (hourlyWage * workHoursPerWeek * 50) / 12 << endl;

   return 0;
}
```

Run

When values are stored in variables as above, the program can read user inputs for those values. If a value will never change, the variable can be defined as const.

P Participation Activity

2.18.2: Calculate salary: Generalize a program with variables and input.

The program below has been generalized to read a user's input value for hourlyWage.

1. Run the program. Notice the user's input value of 10 is used. Modify that input value, and run again.
2. Generalize the program to get user input values for workHoursPerWeek and workWeeksPerYear (change those variables' initializations to 0). Run the program.
3. monthsPerYear will never change, so define that variable as const. Use the standard for naming constant variables. Ex: const int MAX_LENGTH = 99. Run the program.
4. Change the values in the input area below the program, and run the program again.

Reset

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

int main() {
   int hourlyWage       = 0;
   int workHoursPerWeek = 40;
   int workWeeksPerYear = 50;
   int monthsPerYear    = 12; // FIXME: Define as const and use stan
   int annualSalary     = 0;
   int monthlySalary    = 0;

   cout << "Enter hourly wage: " << endl;
   cin >> hourlyWage;

   // FIXME: Get user input values for workHoursPerWeek and workWeek

   annualSalary = hourlyWage * workHoursPerWeek * workWeeksPerYear;
   cout << "Annual Salary is: ";
   cout << annualSalary << endl;

   // FIXME: Change monthsPerYear to the const variable that uses th
```

```
10
```

Run

Section 2.19 - C++ example: Married-couple names with variables

P Participation Activity

2.19.1: Married-couple names with variables.

Pat Smith and Kelly Jones are engaged. What are possible last name combinations for the married couple (listing Pat first)?

1. Run the program below to see three possible married-couple names. Note the use of variable firstNames to hold both first names of the couple.
2. Extend the program to define and use a variable lastName similarly. Note that the output statements are neater. Run the program again.
3. Extend the program to output two more options that abut the last names, as in SmithJones and JonesSmith. Run the program again.

Reset

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

int main() {
   string firstName1 = "";
   string lastName1  = "";
   string firstName2 = "";
   string lastName2  = "";
   string firstNames = "";
   // FIXME: Define lastName

   cout << "What is the first person's first name?" << endl;
   cin >> firstName1;
   cout << "What is the first person's last name?" << endl;
   cin >> lastName1;

   cout << "What is the second person's first name?" << endl;
   cin >> firstName2;
   cout << "What is the second person's last name?" << endl;
   cin >> lastName2;
```

```
Pat
Smith
Kelly
```

Run

P Participation Activity

2.19.2: Married-couple names with variables (solution).

A solution to the above problem follows:

Reset

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

int main() {
   string firstName1 = "";
   string lastName1  = "";
   string firstName2 = "";
   string lastName2  = "";
   string firstNames = "";
   string lastName   = "";

   cout << "What is the first person's first name?" << endl;
   cin >> firstName1;
   cout << "What is the first person's last name?" << endl;
   cin >> lastName1;

   cout << "What is the second person's first name?" << endl;
   cin >> firstName2;
   cout << "What is the second person's last name?" << endl;
   cin >> lastName2;
```

```
Pat
Smith
Kelly
```

Run