Overview of C Programming

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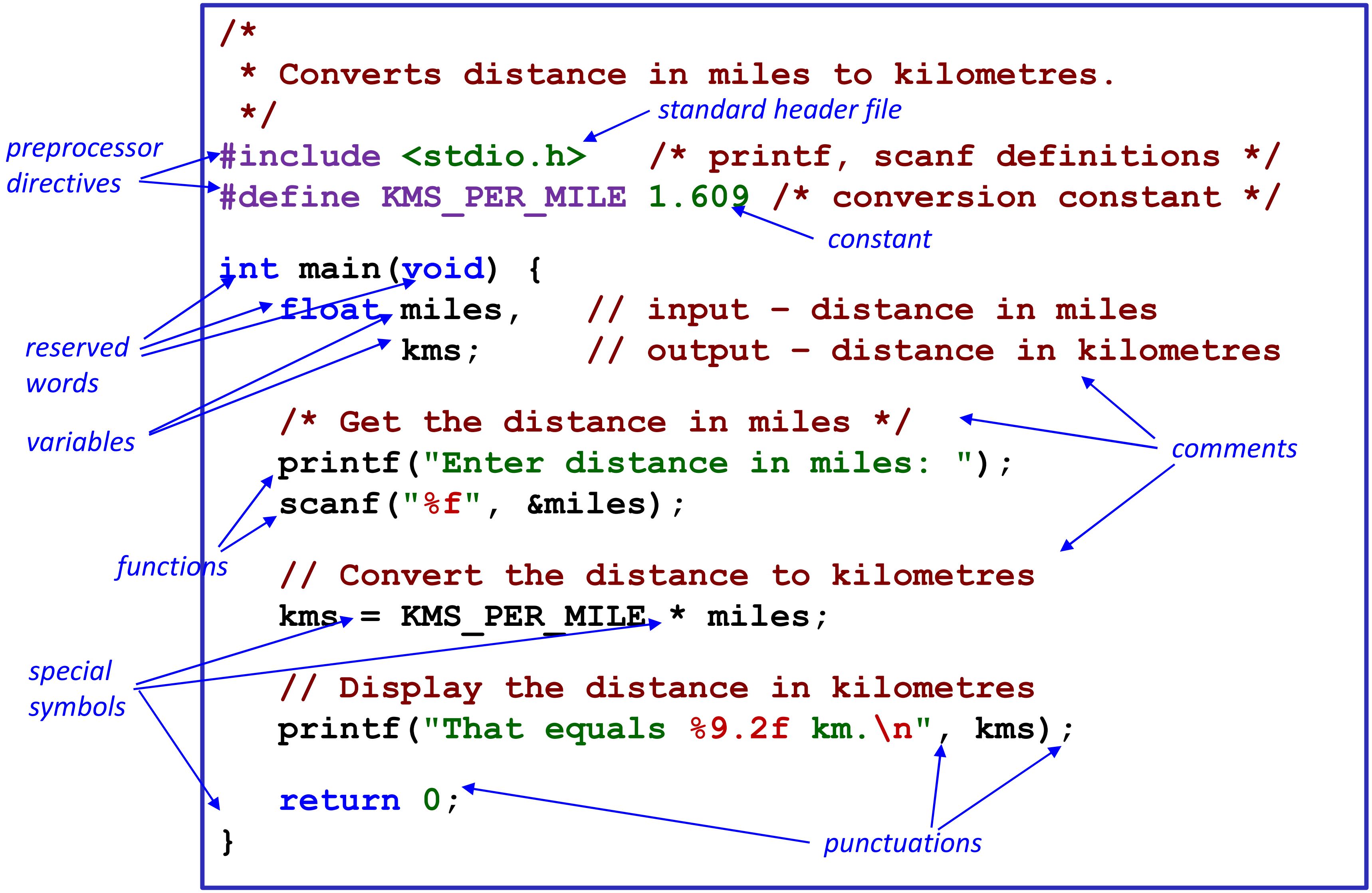
Outline

- History of C
- C Language Elements
- Data Types and Variable Declarations
- Executable Statements
- Input and Output Functions
- General form of a C program
- Arithmetic Expressions
- Formatting Numbers in Program Output

History of C

- C was developed in 1972 by Dennis Ritchie at AT&T Bell Laboratories.
- C was designed as a programming language to write the Unix Operating System.
- C became the most commonly used language for writing system software.
- C is machine independent: C programs can be compiled to run on a wide variety of processors and operating systems.

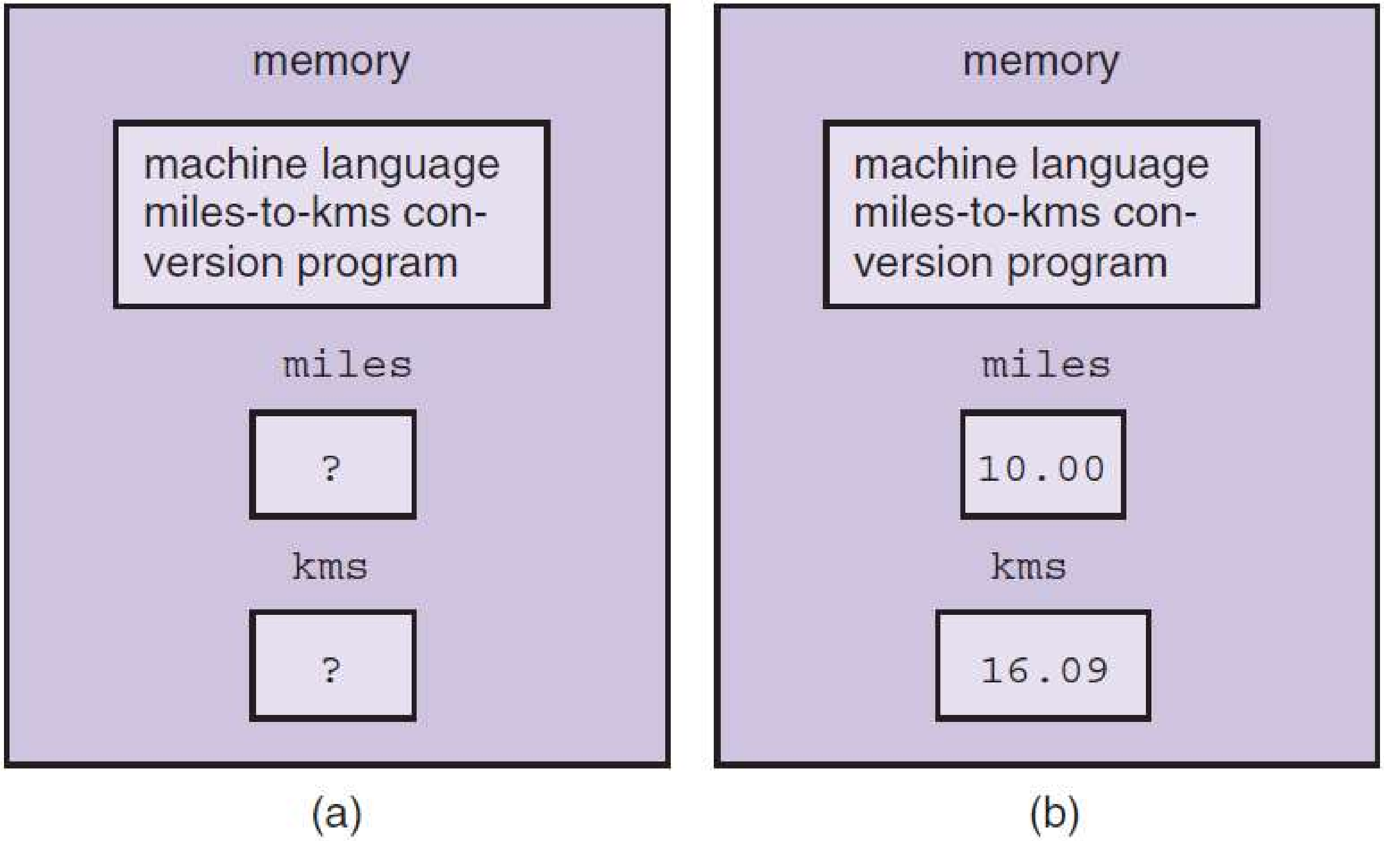
C Language Elements in Miles-to-Kilometers Conversion Program



```
/*
 * Converts distance in miles to kilometres.
 */
#include <stdio.h>   /* printf, scanf definitions */
#define KMS_PER_MILE 1.609 /* conversion constant */

int main(void) {
   float miles,   // input - distance in miles
         kms;     // output - distance in kilometres

   /* Get the distance in miles */
   printf("Enter distance in miles: ");
   scanf("%f", &miles);

   // Convert the distance to kilometres
   kms = KMS_PER_MILE * miles;

   // Display the distance in kilometres
   printf("That equals %9.2f km.\n", kms);

   return 0;
}
```

Program in Memory: Before (a) and After Execution of a Program (b)

What happens in the computer memory?


memory
machine language miles-to-kms conversion program
miles
?
kms
?
(a)
memory
machine language miles-to-kms conversion program
miles
10.00
kms
16.09
(b)

Preprocessor Directives

- Preprocessor directives are commands that give instructions to the C preprocessor.
- The preprocessor modifies a C program prior to its compilation.
- Preprocessor directives begin with **#**

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

  - Includes Standard I/O Library header file (**.h** file)

```
#include <math.h>
```

  - Includes Standard Math Library header file (**.h** file)

```
#define PI 3.141593
```

  - Defines the constant **PI**

#include Directives

- **`#include`** directive is used to include other source files into your source file.
- The **`#include`** directive gives a program access to a standard library.
- **Standard Libraries** contains useful functions and symbols that are predefined by the C language.
  - You must include **`<stdio.h>`** if you want to use the **`printf`** and **`scanf`** library functions.
  - **`stdio.h`** is called a header file (**`.h`** file). It contains information about standard input and output functions that are inserted into your program before compilation.

#define Directives

- The **#define** directive instructs the preprocessor to replace each occurrence of a text by a particular constant value before compilation.
- **#define** replaces all occurrences of the text you specify with the **constant value** you specify

```
#define NAME value
#define KMS_PER_MILE 1.609
#define PI 3.141593
```

The main Function

- **`int main(void)`** marks the beginning of the **`main`** function where program execution begins.
- Every C program has a **`main`** function.
- Braces **{** and **}** mark the beginning and end of the body of function main.
- A function body has two parts:
  - **Declarations** - tell the compiler what memory cells are needed in the function
  - **Executable statements** - (derived from the algorithm) are translated into machine language and later executed by the computer

Reserved Words

- A word that has special meaning to C and can not be used for other purposes.
- These are words that C reserves for its own uses
- Built-in Types: **`int`**, **`float`**, **`double`**, **`char`**, etc.
- Control flow: **`if`**, **`else`**, **`for`**, **`while`**, **`return`**, etc.
- Always lower case

Standard Identifiers

- **Identifier** - A name given to a variable or a function
- **Standard Identifier** - An identifier defined in a standard C library and has special meaning in C.
  - Examples: `printf, scanf`
  - Standard identifiers are not reserved words
  - You can redefine standard identifiers if you want to, but it is not recommended.
  - For example, if you define your own function `printf`, then you cannot use the C library function `printf`.

User Defined Identifiers

- We choose our own identifiers to
  - Name memory cells that will hold data and program results
  - Name functions that we define
- **Rules for Naming Identifiers:**
  - An identifier consists only of letters, digits, and underscores
  - An identifier cannot begin with a digit
  - A C reserved word cannot be used as an identifier
  - A standard C identifier should not be redefined
- Examples of Valid identifiers:
  - `letter1, inches, KMS_PER_MILE`
- Examples of Invalid identifiers:
  - `1letter, Happy$trout, return`

Guidelines for Naming Identifiers

- Uppercase and lowercase are different
  - `LETTER` , `Letter`, `letter` are different identifiers
  - Avoid names that only differ by case. They can lead to problems of finding bugs (errors) in the program.
- Choose meaningful identifiers (easy to understand)
- Example: `distance = rate * time`
  - Means a lot more than `z = x * y`
- Choose `#define` constants to be ALL UPPERCASE
  - Example: `KMS_PER_MILE` is a defined constant
  - As a variable, we can probably name it:

    `KmsPerMile` or `Kms_Per_Mile`

Data Types

- **Data Types**: a set of values and a set of operations that can be performed on those values
  - `int`: Stores signed integer values: whole numbers
    - Examples: `65`, `-12345`
  - `double`: Stores real numbers that use a decimal point
    - Examples: `3.14159` or `1.23e5` (which equals `123000.0`)
  - `char`: Stores character values
    - Each char value is enclosed in single quotes: `'A'`, `'*'`
    - Can be a letter, digit, or special character symbol
  - Arithmetic operations (`+`, `-`, `*`, `/`) and compare can be performed on `int` and `double` variables. Compare operations can be performed on `char` variables.

Integer and Floating-Point Data Types

- Integer Types in C

Type	Size in Memory	Range
short	2 bytes = 16 bits	-32768 to +32767
unsigned short	2 bytes = 16 bits	0 to 65535
int	4 bytes = 32 bits	-2147483648 to +2147483647
unsigned int	4 bytes = 32 bits	0 to 4294967295
long	4 bytes = 32 bits	Same as int
long long	8 bytes = 64 bits	-9×10^{18} to $+9\times10^{18}$

- Floating-Point Types in C

Type	Size in Memory	Approximate Range	Significant Digits
float	4 bytes = 32 bits	10^{-38} to 10^{+38}	6
double	8 bytes = 64 bits	10^{-308} to 10^{+308}	15

Characters and ASCII Code

- Character Type in C

Type	Size in Memory	ASCII Codes
char	1 byte = 8 bits	0 to 255

- ASCII Codes and Special Characters

Character	ASCII Code
'0'	48
'9'	57
'A'	65
'B'	66
'Z'	90
'a'	97
'b'	98
'z'	122

Special Characters	Meaning
' '	Space Character
'*'	Star Character
'\n'	Newline
'\t'	Horizontal Tab
'\''	Single Quote
'\"'	Double Quote
'\\'	Backslash
'\0'	NULL Character

Variable Declaration

- **Variables:** The memory cells used for storing a program's input data and its computational results
  - The Value of a Variable can change at runtime
- **Variable declarations**: Statements that communicate to the compiler the names of variables in the program and the type of data they can store.
  - Examples:

```
double miles, kms;
int    count;
char   answer;
```

  - C requires that you declare every variable in the program.

Executable Statements

- Executable Statements: C statements used to write or code the algorithm. C compiler translates the executable statements to machine code.
- Examples of executable Statements:
  - Assignment Statements
  - Function Calls, such as calling **`printf`** and **`scanf`**
  - **`return`** statement
  - **`if`** and **`switch`** statements (selection) - later
  - **`for`** and **`while`** statements (iteration) - later

Assignment Statements

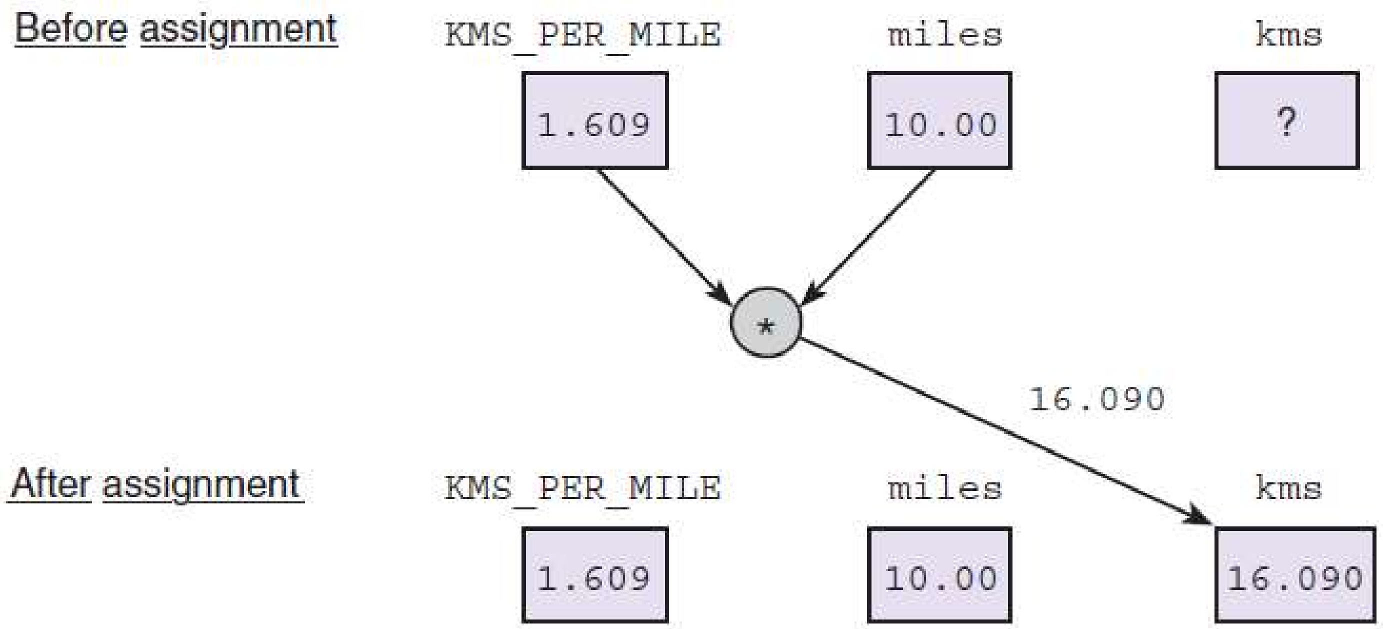
- Stores a value or a computational result in a variable

```
variable = expression;
```

`=` is the **Assignment Operator**

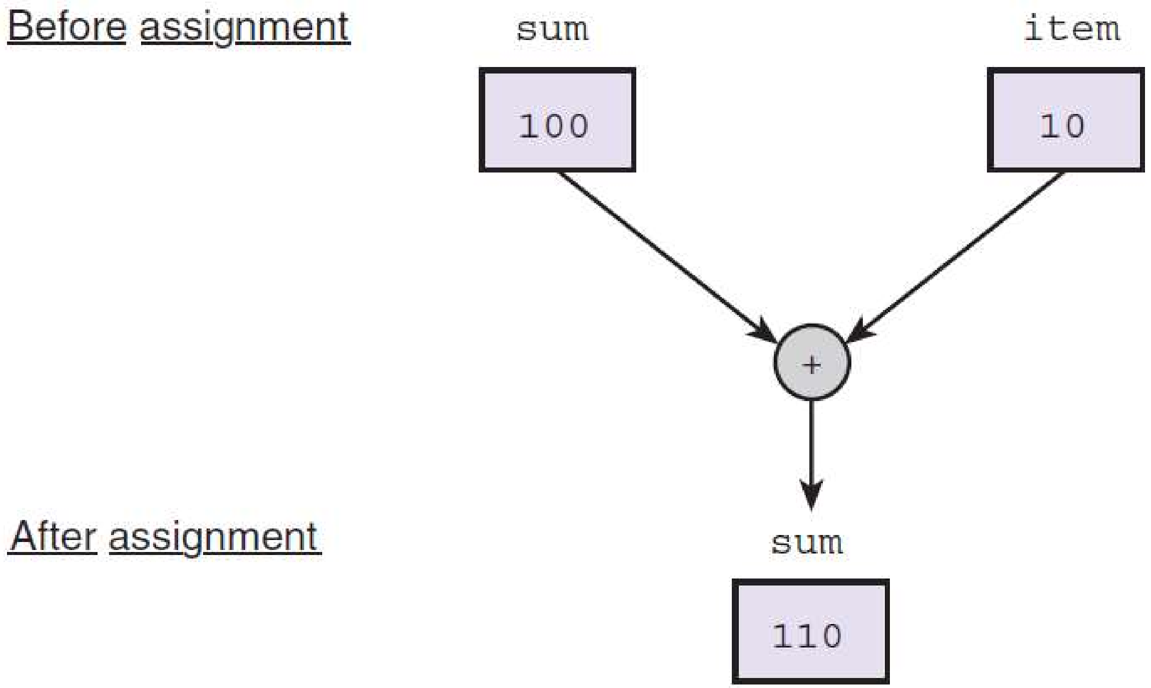
- The assignment statement computes the expression that appears after the assignment operator and stores its value in the variable that appears to the left.

Effect of
kms = KMS_PER_MILE * miles



The value assigned to **`kms`** is the result of multiplying the constant **`KMS_PER_MILE`** by the variable **`miles`**.

Effect of
sum = sum + item



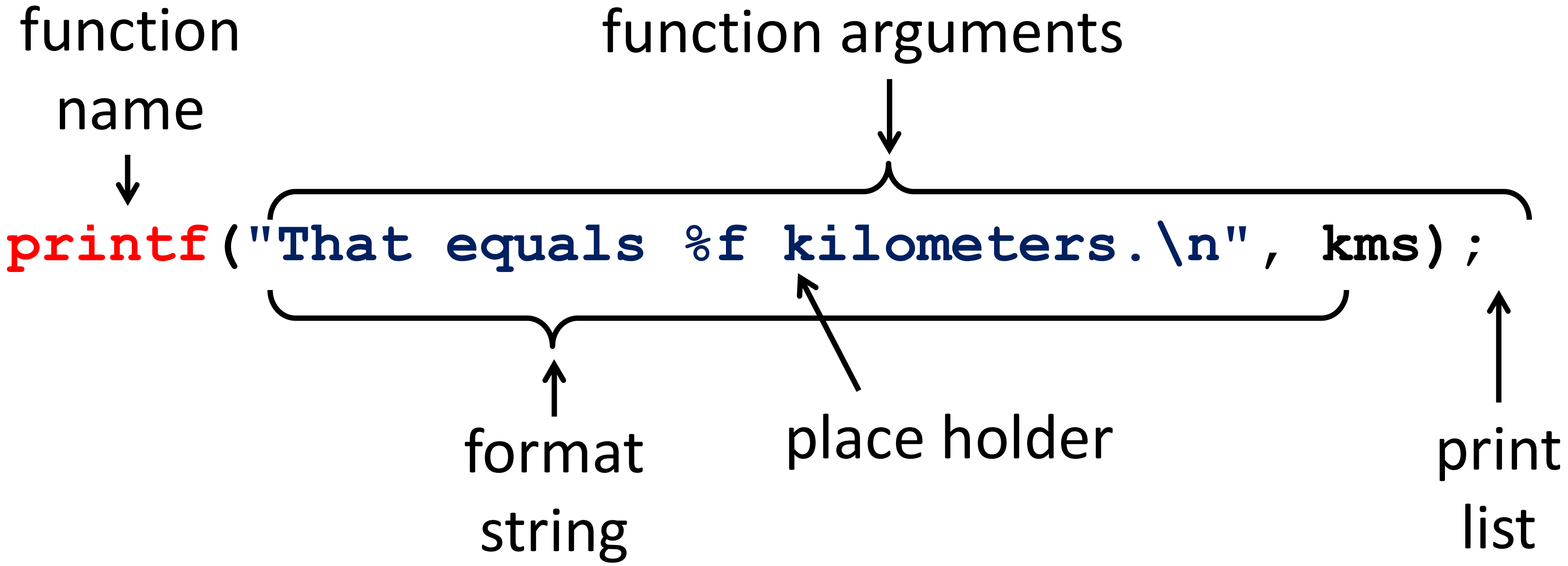
Read = as "becomes"

The assignment operator does NOT mean equality

Input/Output Operations and Functions

- **Input operation:** data transfer from the outside world into computer memory
- **Output operation:** program results can be displayed to the program user
- **Input/Output functions:** special program units that do all input/output operations
  - `printf` : output function
  - `scanf` : input function
- **Function call:** used to call or activate a function
  - Asking another piece of code to do some work for you

The printf function



function name

function arguments

```
printf("That equals %f kilometers.\n", kms);
```

format string

place holder

print list

That equals 16.0900000 kilometers.

Placeholders

- Placeholders always begin with the symbol %
  - % marks the place in a format string where a value will be printed out or will be read
- Format strings can have multiple placeholders, if you are printing multiple values

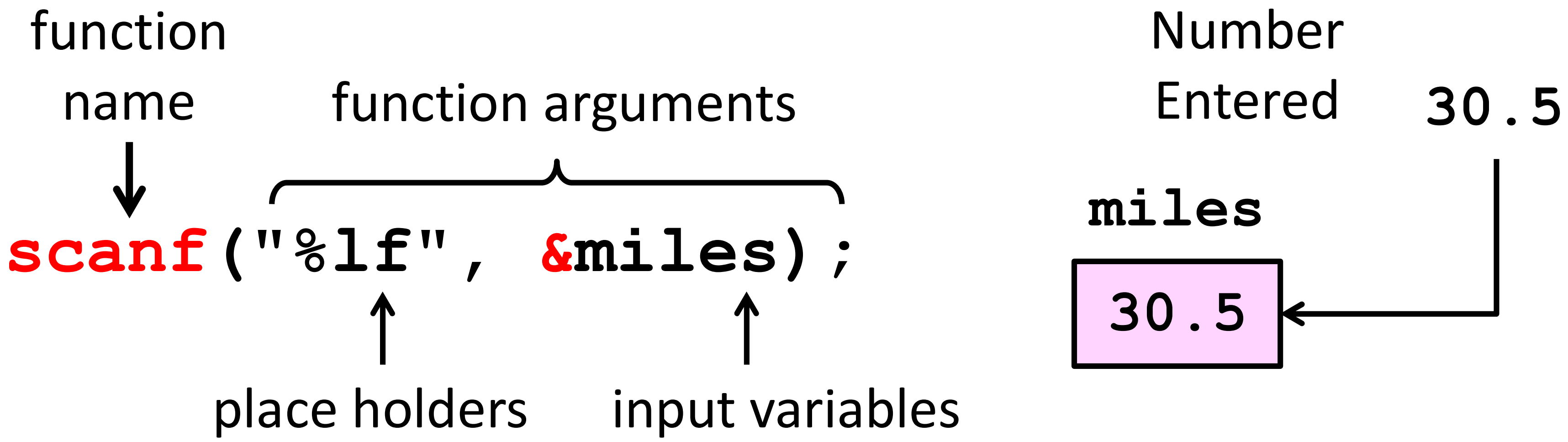
Placeholder	Variable Type	Function Use
%c	char	printf / scanf
%d	int	printf / scanf
%f	double	printf
%lf	double	scanf

Displaying Prompts

- When input data is needed in an interactive program, you should use the **`printf`** function to display a **prompting message**, or **prompt**, that tells the user what data to enter.

```
printf("Enter the distance in miles> ");
printf("Enter the object mass in grams> ");
```

The scanf Function



function name

function arguments

scanf("%lf", &miles);

place holders

input variables

Number Entered

30.5

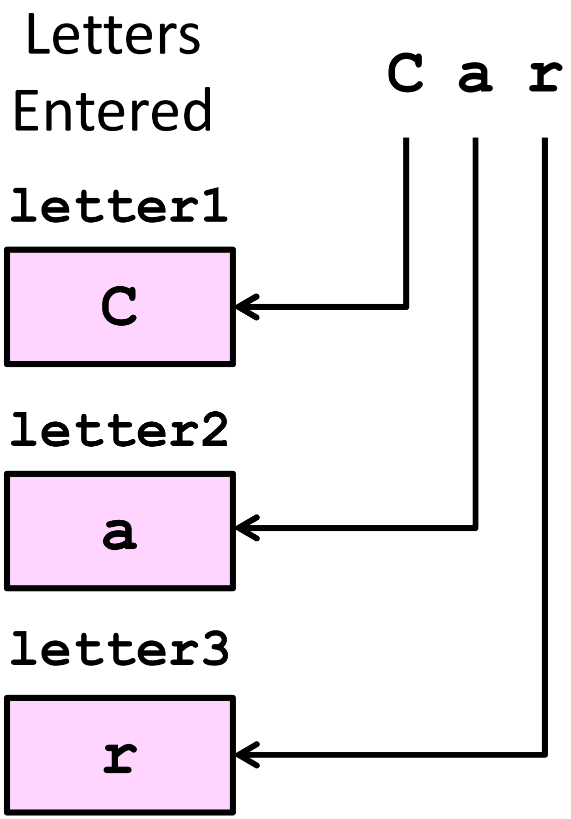
miles

30.5

- The **&** is the **address operator**. It tells **scanf** the address of variable **miles** in memory.
- When user inputs a value, it is stored in **miles**.
- The placeholder **%lf** tells **scanf** the type of data to store into variable miles.

Reading Three Letters

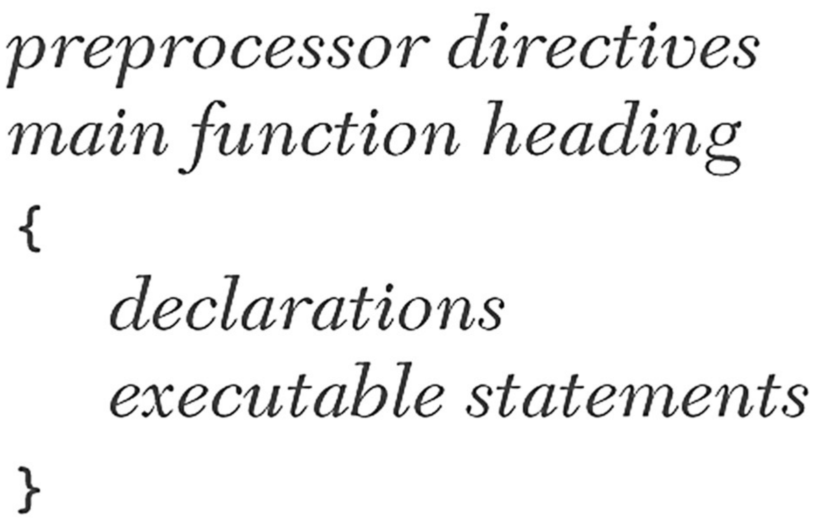
```
char letter1, letter2, letter3;

scanf("%c%c%c",

       &letter1,

       &letter2,

       &letter3);
```



Return Statement

- Syntax: `return` ***`expression`*** `;`
- Example: `return (0);`
- Returning from the main function terminates the program and transfers control back to the operating system. Value returned is `0`.
- The `return` statement transfers control from a function back to the caller.
- Once you start writing your own functions, you will use the `return` statement to return the result of a function back to the caller.

General Form of a C program



```
preprocessor directives
main function heading
{
    declarations
    executable statements
}
```

- Preprocessor directives modify the text of a C program before compilation.
- Every variable has to be declared before using it.

- Executable statements are translated into machine language and eventually executed.
- Executable statements perform computations on the declared variables or input/output operations.

Comments

- Comments making it easier for us to understand the program, but are ignored by the C compiler.
- Two forms of comments:
  - `/* C comment */` anything between `/*` and `*/` is considered a comment, even if it spans on multiple lines.
  - `// C++ comment` anything after `//` is considered a comment until the end of the line.
- Comments are used to create **Program Documentation**
  - Help others read and understand the program.
- The start of the program should consist of a comment that includes programmer's name, date, current version, and a brief description of what the program does.
- **Always Comment your Code!**

Programming Style

- Why we need to follow conventions?
  - A program that looks good is easier to read and understand than one that is sloppy.
  - 80% of the cost of software goes to maintenance.
  - Hardly any software is maintained for its whole lifetime by the original author.
  - Programs that follow the typical conventions are more readable and allow engineers to understand the code more quickly and thoroughly.
- Check your text book and expert programmers on how to improve your programming style.

White Space

- The compiler ignores extra blanks between words and symbols, but you may insert space to improve the readability and style of a program.
- You should always leave a blank space after a comma and before and after operators such as: **`+  –  *  /`** and **`=`**
- You should indent the lines of code in the body of a function.

White Space

Bad:

```
int main(void)
{ int foo,blah;
scanf("%d",&foo);
blah=foo+1;
printf("%d", blah);
return 0;}
```

Good:

```
int main(void)
{
  int foo, blah;
  scanf("%d", &foo);
  blah = foo + 1;
  printf("%d", blah);
  return 0;
}
```

Bad Programming Practice

- Missing statement of purpose
- Inadequate commenting
- Variables names are not meaningful
- Use of unnamed constant
- Indentation does not represent program structure
- Algorithm is inefficient or difficult to follow
- Program does not compile
- Program produces incorrect results
- Insufficient testing (test case results are different than expected, program is not fully tested for all cases)

Arithmetic Expressions

- To solve most programming problems, you need to write arithmetic expressions that compute data of type `int` and `double` (and sometimes `char`)
- Arithmetic expressions contain variables, constants, function calls, arithmetic operators, as well as sub-expressions written within parentheses.
- Examples:
  - `sum + 1`
  - `(a + b) * (c - d)`
  - `(-b + sqrt(delta))/(2.0 * a)`

Arithmetic Operators

Operator	Meaning	Examples
+	addition	5 + 2 is 7 5.0 + 2.0 is 7.0 'B' + 1 is 'C'
–	subtraction	5 – 2 is 3 5.0 – 2.0 is 3.0 'B' – 1 is 'A'
*	multiplication	5 * 2 is 10 5.0 * 2.0 is 10.0
/	division	5 / 2 is 2 5.0 / 2.0 is 2.5
%	remainder	5 % 2 is 1

Operators / And %

Example	Result	Explanation
8 / 5	1	Integer operands → integer result
8.0/5.0	1.6	floating-point operands and result
8 /-5	-1	One operand is negative → negative result
-8 /-5	1	Both operands are negative → positive result
8 % 5	3	Integer remainder of dividing 8 by 5
8 %-5	3	Positive dividend → positive remainder
-8 % 5	-3	Negative dividend → Negative remainder

- **`(m/n)*n + (m%n)`** **is always equal to** **`m`**
- **`/`** and **`%`** are undefined when the divisor is **0**.

Data Type of an Expressions

- What is the type of expression **`x+y`** when **`x`** and **`y`** are both of type **`int`**? (answer: type of **`x+y`** is **`int`**)
- The data type of an expression depends on the type(s) of its operands
  - If both are of type **`int`**, then the expression is of type **`int`**.
  - If either one or both operands are of type **`double`**, then the expression is of type **`double`**.
- An expression that has mixed operands of type **`int`** and **`double`** is a **mixed-type** expression.

Multi-Type Assignment Statement

- The expression being evaluated and the variable to which it is assigned have **different data types**
- The expression is first evaluated; then the result is assigned to the variable to the left side of = operator
  - Example: what is the value of **y = 5/2** when **y** is of type **`double`**? (answer: **5/2** is **2**; **y = 2.0**)
- **Warning**: assignment of a type **`double`** expression to a type **`int`** variable causes the fractional part of the expression to be lost.
  - Example: what is the type of the assignment **y = 5.0 / 2.0** when **y** is of type **`int`**? (answer: **5.0/2.0** is **2.5**; **y = 2**)

Type Conversion Through Casts

- C allows the programmer to convert the type of an expression by placing the desired type in parentheses before the expression.
- This operation is called a **type cast**.
  - **`(double)5 / (double)2`** is the **`double`** value **2.5**
  - **`(int)(9 * 0.5)`** is the **`int`** value **`4`**
- When casting from **`double`** to **`int`**, the decimal fraction is truncated (NOT rounded).

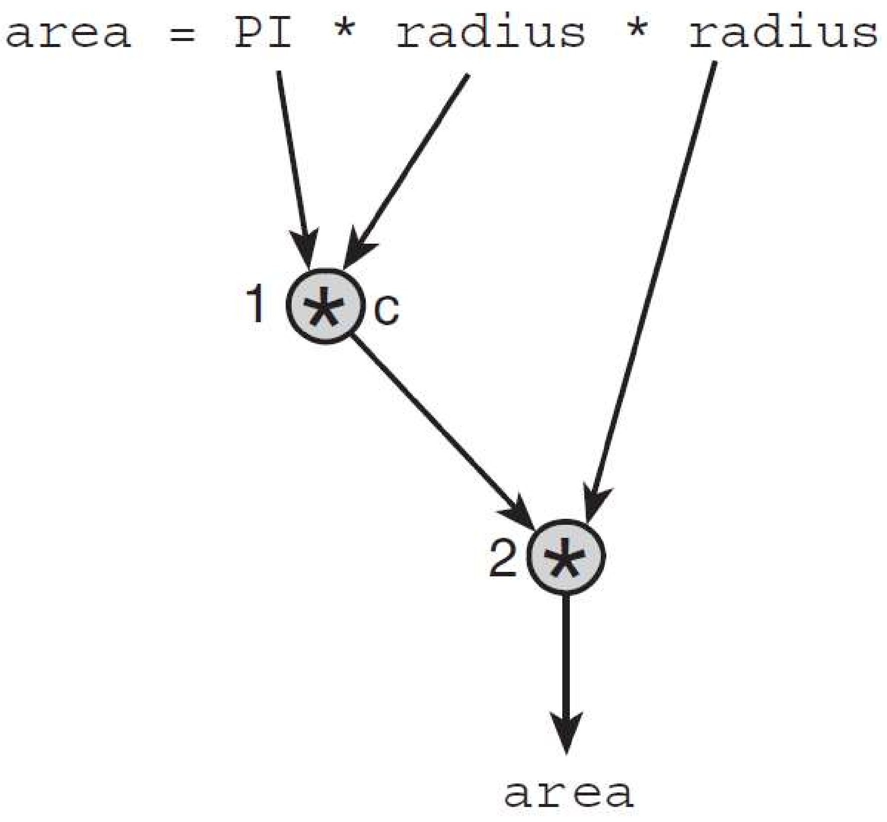
Example of the Use of Type Cast

```
/* Computes a test average  */
#include <stdio.h>

int main(void)
{
  int       total;      /* total score */
  int       students;   /* number of students */
  double    average;    /* average score */

  printf("Enter total students score> ");
  scanf("%d", &total);
  printf("Enter number of students> ");
  scanf("%d", &students);
  average = (double) total / (double) students;
  printf("Average score is %.2f\n", average);
  return 0;
}
```

Expression with Multiple Operators

- Operators are of two types: **unary** and **binary**
- **Unary operators** take only one operand
  - **Unary minus (-) and Unary plus (+) operators**
- **Binary operators** take two operands
  - **Examples: addition (+), subtraction (–), multiplication (*), division (/) and integer remainder (%) operators**
- A single expression could have multiple operators
  - Example: `-a + b*c - d/2`

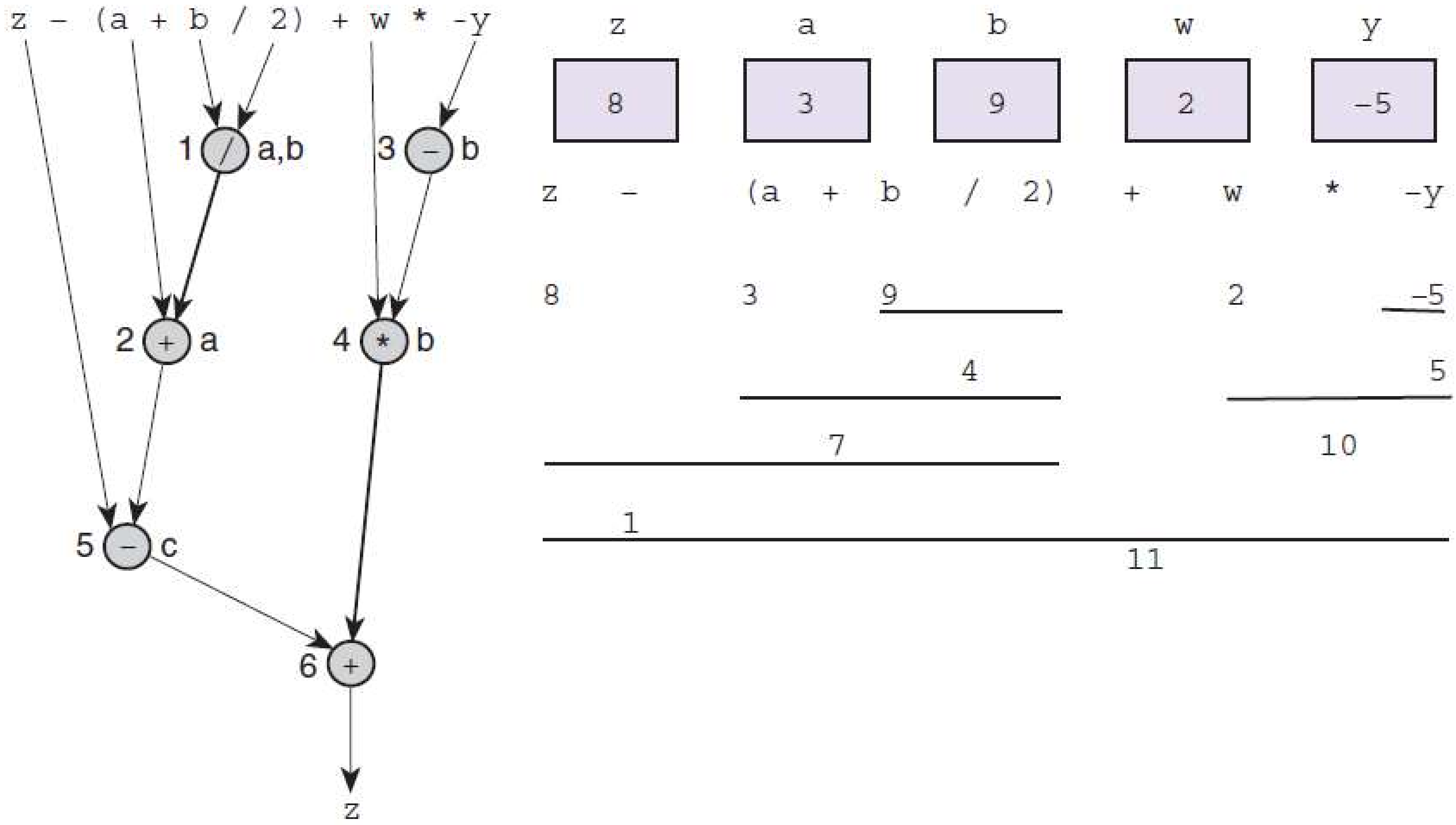
Step-by-Step Expressions Evaluation



area = PI * radius * radius

```
area    =        PI     *    radius     *    radius
             3.14159           2.0             2.0
             ___________________________
                   6.28318
                   ______________________________________
                                   12.56636
```

Evaluate: `z - (a + b/2) + w*-y`



Formatting Integers in Program Output

- You can specify how `printf` will display integers
- For integers, use **%nd**
  - **%** start of placeholder
  - **n** is the optional field width = number of columns to display
  - If **n** is less than integer size, it will be ignored
  - If **n** is greater than integer size, spaces are added to the left

Value	Format	Output		Value	Format	Output
234	%4d	□234		-234	%4d	-234
234	%5d	□□234		-234	%5d	□-234
234	%6d	□□□234		-234	%6d	□□-234
234	%1d	234		-234	%2d	-234

Formatting Type Double Values

- Use **%n.mf** for **double values**
  - **n** is the optional field width = number of digits in the whole number, the unary minus, decimal point, and fraction digits
  - If **n** is less than what the number needs it will be ignored
  - **.m** is the number of decimal places (optional)

Value	Format	Output	Value	Format	Output
3.14159	%5.2f	□3.14	3.14159	%4.2f	3.14
3.14159	%3.2f	3.14	3.14159	%5.1f	□□3.1
3.14159	%5.3f	3.142	3.14159	%8.5f	□3.14159
0.1234	%4.2f	0.12	-0.006	%4.2f	-0.01
-0.006	%8.3f	□□-0.006	-0.006	%8.5f	-0.00600
-0.006	%.3f	-0.006	-3.14159	%.4f	-3.1416

Expression with Multiple Operators

- **Syntax Errors (Detected by the Compiler)**
  - Violating one or more grammar rules
  - Missing semicolon (end of variable declaration or statement)
  - Undeclared variable (using a variable without declaration)
  - Comment not closed (missing */ at end of comment)
- **Run-Time Errors (NOT detected by compiler)**
  - Detected by the computer when running the program
  - Illegal operation, such as dividing a number by zero
  - Program cannot run to completion
- **Undetected and Logic Errors**
  - Program runs to completion but computes wrong results
  - Input was not read properly
  - Wrong algorithm and computation