ELE108 lecture 3

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Overview

- C Arithmetic Expressions
- Formatting Numbers in Program Output
- Interactive Mode, Batch Mode, and Data Files
- Common Programming Errors
- Programming Style

Arithmetic Expressions

- Operators
- Data Type of Expression
- Mixed-Type Assignment Statement
- Type Conversion through Cast
- Expressions with Multiple Operators
- Writing Mathematical Formulas in C

Why Arithmetic Expressions

- To solve most programming problems, you will need to write arithmetic expressions that manipulate type `int` and `double` data.
- The next slide shows all arithmetic operators. Each operator manipulates **two operands**, which may be constants, variables, or other arithmetic expressions.
- Example
  - 5 + 2
  - sum + (incr* 2)
  - (B/C) + (A + 0.5)

C Operators

Arithmetic Operator	Meaning	Examples
+ (*int*,*double*)	Addition	5 + 2 is 7 5.0 + 2.0 is 7.0
- (*int*,*double*)	Subtraction	5 - 2 is 3 5.0 - 2.0 is 3.0
* (*int*,*double*)	Multiplication	5 * 2 is 10 5.0 * 2.0 is 10.0
/ (*int*,*double*)	Division	5 / 2 is 2 5.0 / 2.0 is 2.5
% (*int*)	Remainder	5 % 2 is 1

Operator / & %

- **Division**: When applied to two positive integers, the division operator (/) computes the integral part of the result by dividing its first operand by its second.
  - For example 7.0 / 2.0 is 3.5 but the but 7 / 2 is only 3
  - The reason for this is that C makes the answer be of the same type as the operands.
- **Remainder**: The remainder operator (%) returns the integer remainder of the result of dividing its first operand by its second.
  - Examples: 7 % 2 = 1, 6 % 3 = 0
  - The value of m%n must always be less than the divisor n.
  - / is undefined when the divisor (second operator) is 0.

Data Type of an Expression

- The data type of each variable must be specified in its declaration, but how does C determine the data type of an expression?
  - Example: What is the type of expression `x+y` when both `x` and `y` are of type `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 is of type `double`, then the expression is of type `double`.
- An expressions that has operands of both `int` and `double` is a **mixed-type** expression.

Mixed-Type Assignment Statement

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

Type Conversion Through Casts

- C allows the programmer to convert the type of an expression.
- This is done by placing the desired type in parentheses before the expression.
- This operation called a **type cast**.
  - `(double)(5/2)` is the `double` value 2.5, and not 2 as seen earlier.
  - `(int)(3.0/2.0)` is the `int` value 1
- When casting from `double` to `int`, the decimal portion is just truncated – *not* rounded.

Expressions with Multiple Operators

- Operators can be split into two types: **unary** and **binary.**
- **Unary operators** take only one operand
  - **-** (negates the value it is applied to)
- **Binary operators** take two operands.
  - **+,-,*,/**
- A single expression could have multiple operators
  - -5 + 4 * 3 - 2

Rules for Evaluating Expressions

- **Rule (a): Parentheses rule** - All expressions in parentheses must be evaluated separately.
  - Nested parenthesized expressions must be evaluated from the inside out, with the innermost expression evaluated first.
- **Rule (b): Operator precedence rule –** Multiple operators in the same expression are evaluated in the following order:
  - First: unary –
  - Second: *, /, %
  - Third: binary +,-
- **Rule (c): Associativity rule**
  - Unary operators in the same subexpression and at the same precedence level are evaluated right to left
  - Binary operators in the same subexpression and at the same precedence level are evaluated left to right.

Figure 2.8 Evaluation Tree for area = PI * radius * radius;

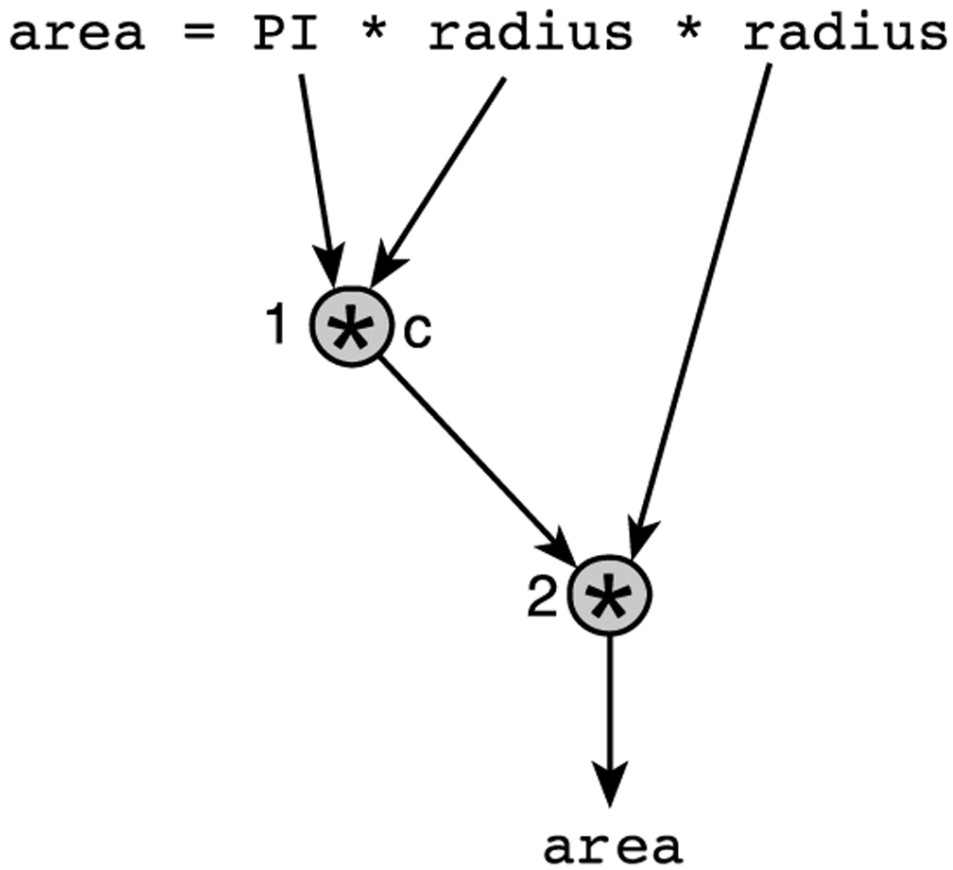
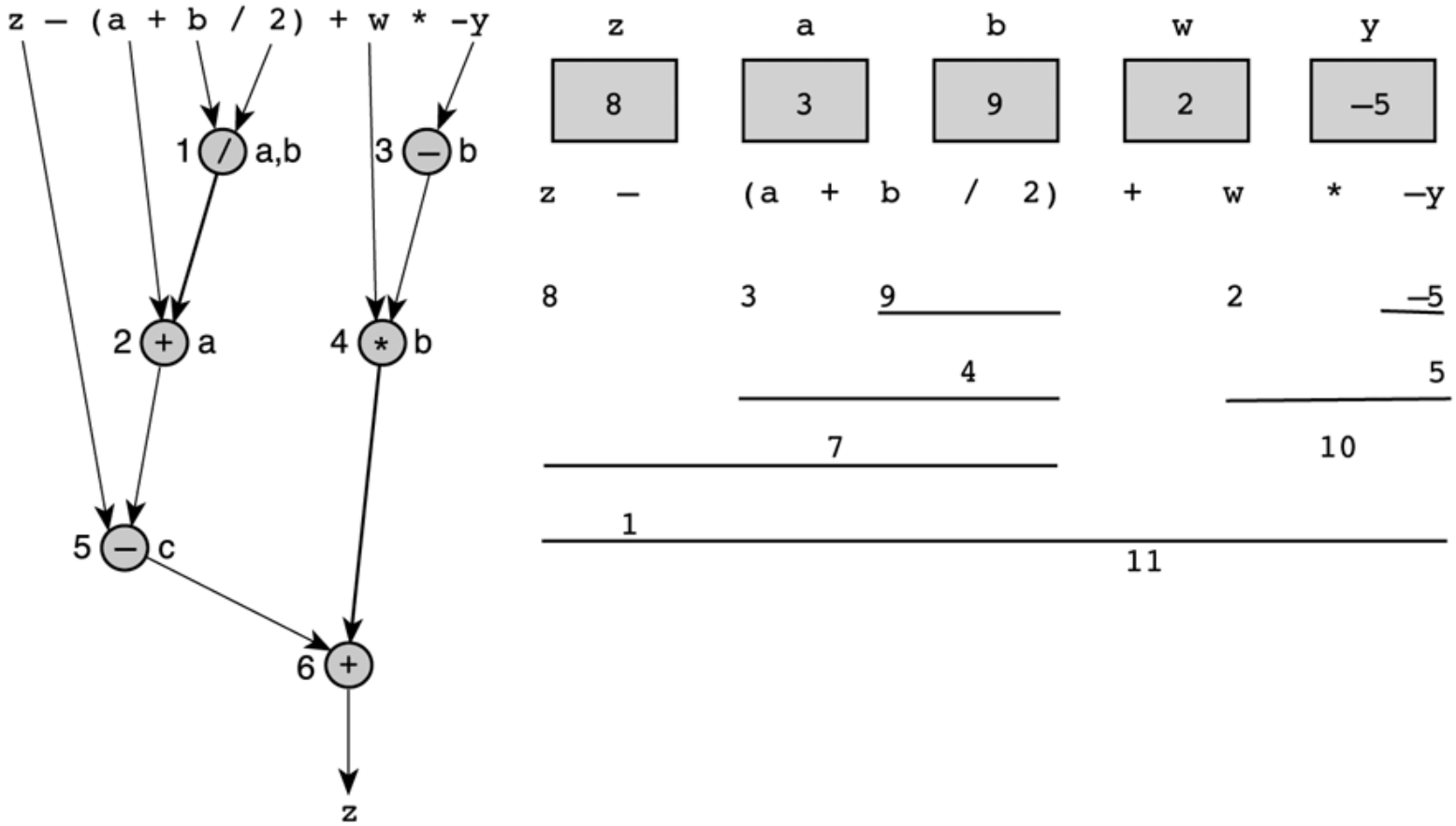


Figure 2.11 Evaluation Tree and Evaluation for z - (a + b / 2) + w * -y



Writing Mathematical Formulas in C

- You may encounter two problems in writing a mathematical formula in C.
- First, multiplication often can be implied in a formula by writing two letters to be multiplied next to each other. In C, you must state the * operator
  - For example, 2a should be written as 2 * a.
- Second, when dealing with division we often have:

$$\frac{a+b}{c+d}$$

  - This should be coded as (a + b) / (c + d).

Formatting Numbers in Program Output (for integers)

- You can specify how `printf` will display numeric values
- Use d for integers. %#d
  - % - start of placeholder
  - # - field width (optional) – the number of columns to use to display the output.
  - d - placeholder for integers

```
int n = 123;
printf("%1d\n", n);      123
printf("%3d\n", n);      123
printf("%4d\n", n);       123
```

TABLE 2.11 Displaying 234 and -234 Using Different Placeholders

Value	Format	Displayed Output	Value	Format	Displayed 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 Numbers in Program Output (for double)

- Use %n.mf for double
  - % - start of placeholder
  - n - field width (optional)
  - m – Number of decimal places (optional)
  - f - placeholder for real numbers

```
double n = 123.456;
printf("%8.0f\n", n);          123
printf("%8.2f\n", n);        123.46
printf("%8.3f\n", n);       123.456
printf("%8.4f\n", n);      123.4560
Printf("%.2f\n", n);       123.46
```

TABLE 2.12 Displaying x Using Format String Placeholder %6.2f

Value of x	Displayed Output	Value of x	Displayed Output
-99.42	-99.42	-25.554	-25.55
.123	␣␣0.12	99.999	100.00
-9.536	␣-9.54	999.4	999.40

TABLE 2.13 Formatting Type double Values

Value	Format	Displayed Output	Value	Format	Displayed 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
.1234	%4.2f	0.12	-.006	%4.2f	-0.01
-.006	%8.3f	␣␣-0.006	-.006	%8.5f	-0.00600
-.006	%.3f	-0.006	-3.14159	%.4f	-3.1416

Computer operation modes

- Interactive Mode

  user interact with the program and supply the data
- Batch Mode

  the program get the data from a file

  using *redirection*, e.g. metric <mydata

Input Redirection

- In the next frame we will see the miles-to-kilometers conversion program rewritten as a batch program.
- We assume here that the standard input device is associated with a batch data file instead of with the keyboard.
- In most system, this association can be accomplished relatively easily through input/output redirection using operating system commands.
- Instead of calling the program as:

```
$ conversion
```

  We would call it as:

```
$ conversion < myinput
```

- This **redirects** the text in the file `myinput` and uses it as the program input.
- Here `$` represents command prompt.

Miles to Kilometers conversion program in interactive mode

```
/* Converts distances from miles to kilometers */

#include <stdio.h>                      /* printf, scanf definitions */
#define KMS_PER_MILE 1.609              /* conversion constant */

int main(void)
{
    double miles,       //distance in miles
           kms;         //equivalent distance in kilometers

    //Get the distance in miles
    printf("Enter the distance in miles> ");
    scanf("%lf", &miles);

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

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

    return (0);
}
```

Miles to Kilometers conversion program with input redirection.

```
/* Converts distances from miles to kilometers */

#include <stdio.h>                      /* printf, scanf definitions */
#define KMS_PER_MILE 1.609              /* conversion constant */

int main(void)
{
        double miles,           //distance in miles
               kms;             //equivalent distance in kilometers

        //Get and echo the distance in miles
        scanf("%lf", &miles);
        printf("The distance in miles is %.2f.\n", miles);

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

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

        return (0);
}
```

Echo Prints vs. Prompts

- In the above program `scanf` gets a value for miles from the first (and only) line of the data file.
- Because the program input comes from a data file, there is no need to precede this statement with a prompting message.
- Instead, we follow the call to `scanf` with the statement

```
printf("The distance in miles is %.2f.\n",miles);
```

- This statement **echo prints** or displays the value just stored in `miles`.
- Without it, we would have no easy way of knowing what value `scanf` obtained for miles.
- Whenever you convert an interactive program to a batch program, make sure you replace each prompt with an echo print after the `scanf`.

- Output redirection

  metric >myoutput
- Input/output redirections

  metric <mydata >myoutput

Output Redirection

- You can also redirect the output of the program to a file instead of the screen.
- Then you can send the output file to the printer to obtain a hard copy of the program output.
- The command line:

```
$ conversion > myoutput
```

  sends the output of the program `conversion` to the file `myoutput.`
- You can do both input and output redirection by using:

```
$ conversion < myinput > myoutput
```

Program-controlled input/output files

- File pointer:
  FILE *inp, *outp;
- *fopen* function

  inp=fopen(“distance.dat”, “r”);

  outp=fopen(“distance.out”, “w”);
- Access mode

  r, w, a
- *fclose* function

  fclose(inp);

  fclose(outp);

Program Controlled Input and Output Files

- As an alternative to input/output redirection, C allows a program to read/write from/to files within the program.
- To do this, you need to:
  1. Include `stdio.h`
  2. Declare a variable of type `FILE`
  3. Open the file for reading/writing.
  4. Read/write from/to the file.
  5. Close the file.
- In the example (next slide) you will see each of these steps.

Miles to Kilometers conversion using program controlled input/output

```
#include <stdio.h>
#define KMS_PER_MILE 1.609

int main(void) {
        double kms, miles;
        FILE *inp, *outp;

        inp = fopen(“myinput","r");
        outp = fopen(“myoutput","w");
        fscanf(inp, "%lf", &miles);
        fprintf(outp, "The distance in miles is %.2f.\n", miles);

        kms = KMS_PER_MILES * miles;

        fprintf(outp, "That equals %.2f kilometers.\n", kms);
        fclose(inp);
        fclose(outp);
        return (0);
}
```

```
#include <stdio.h>
#define KMS_PER_MILE 1.609
int main(void)
{
  double miles, kms;
  FILE *inp, *outp;

  /* open the input and output files */
  inp = fopen("distance.dat","r");
  outp = fopen("distance.out","w");

  /* Get the distance in miles */
  fscanf(inp,"%lf",&miles);
  fprintf(outp, "The distance in miles is %.2f. \n", miles);

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

  /* Display the distance in kilometers */
  fprintf(outp,"That equals %f kilometers.\n", kms);

  fclose(inp);
  fclose(outp);
  return (0);
}
```

Program errors

- Syntax errors
- Run-time errors
- Undetected errors
- Logic errors

Debugging a program (error correcting process) is necessary

Syntax Errors

- A syntax error occurs when your code violates one or more grammar rules of C
  - This is detected by the compiler as it attempts to translate your program.
  - If a statement has a syntax error, it cannot be translated and your program will not be executed.
- Common syntax errors:
  - Missing semicolon
  - Undeclared variable
  - Last comment is not closed

Syntax errors

- The code violates one or more grammar rules of C and is detected by the complier.
- The complier will list the line number of the error and the possible problem.
- This type of errors are usually caused by mistyping, thus, these errors are easy to find and correct.

```
221 /* Converts distances from miles to kilometers. */
222
223 #include <stdio.h>          /* printf, scanf definitions   */
266 #define KMS_PER_MILE 1.609 /* conversion constant          */
267
268 int
269 main(void)
270 {
271       double kms
272
273       /* Get the distance in miles. */
274       printf("Enter the distance in miles> ");
***** Semicolon added at the end of the previous source line

275       scanf("%lf", &miles);
***** Identifier "miles" is not declared within this scope
***** Invalid operand of address-of operator

276
277       /* Convert the distance to kilometers. */
278       kms = KMS_PER_MILE * miles;
***** Identifier "miles" is not declared within this scope

279
280       /* Display the distance in kilometers. * /
281       printf("That equals %f kilometers.\n", kms);
282
283       return (0);
284 }
***** Unexpected end-of-file encountered in a comment
***** "}" inserted before end-of-file
```

Case Study: Finding the Value of Coins (1/3)

- Write a program to determine the value of a collection of coins
  - e.g., quarters, dimes, nickels, and pennies.
- The algorithmic flow:
  - 1. Get and display the customer's initials.
  - 2. Get the count of each kind of coin.
  - 3. Compute the total value in cents.
  - 4. Find and display the value in dollars and change.

Case Study: Finding the Value of Coins (2/3)

```
1.  /*
2.   * Determines the value of a collection of coins.
3.   */
4.  #include <stdio.h>
5.  int
6.  main(void)
7.  {
8.       char first, middle, last; /* input - 3 initials           */
9.       int pennies, nickels;  /* input - count of each coin type */
10.      int dimes, quarters;   /* input - count of each coin type */
11.      int change;               /* output - change amount       */
12.      int dollars;              /* output - dollar amount
13.      int total_cents;          /* total cents
14.
15.      /* Get and display the customer's initials. */
16.      printf("Type in 3 initials and press return> ");
17.      scanf("%c%c%c", &first, &middle, &last);
18.      printf("Hello %c%c%c, let's see what your coins are worth.\n",
19.             first, middle, last);
20.
21.      /* Get the count of each kind of coin. */
22.      printf("Number of quarters> ");
```

1. Read the initials of the customer

(continued)

Case Study: Finding the Value of Coins

```
23.      scanf("%d", &quarters);
24.      printf("Number of dimes   > ");
25.      scanf("%d", &dimes);
26.      printf("Number of nickels > ");
27.      scanf("%d", &nickels);
28.      printf("Number of pennies > ");
29.      scanf("%d", &pennies);
30.
31.      /* Compute the total value in cents. */
32.      total_cents = 25 * quarters + 10 * dimes +
33.                    5 * nickels + pennies;
34.
35.      /* Find the value in dollars and change. */
36.      dollars = total_cents / 100;
37.      change = total_cents % 100;
38.
39.      /* Display the value in dollars and change. */
40.      printf("\nYour coins are worth %d dollars and %d cents.\n",
41.             dollars, change);
42.
43.      return (0);
44.  }

Type in 3 initials and press return> BMC
Hello BMC, let's see what your coins are worth.
Number of quarters> 8
Number of dimes   > 20
Number of nickels > 30
Number of pennies > 77

Your coins are worth 6 dollars and 27 cents.
```

2. Read the count of each kind of coins

3. Compute the total value in cents

4. Find and display the value in dollars and change

The input can be read from a file instead of from the user.

The output can be written into a file instead of on the screen.

```
1.  /* Converts distances from miles to kilometers.    */
2.
3.  #include <stdio.h>    /* printf, scanf, fprint, fscanf, fopen, fclose
4.                          definitions                */
5.  #define KMS_PER_MILE 1.609 /* conversion constant  */
6.
7.  int
8.  main(void)
9.  {
10.       double miles, /* distance in miles                                */
11.              kms;   /* equivalent distance in kilometers               */
12.       FILE   *inp,  /* pointer to input file                           */
13.              *outp; /* pointer to output file                          */
14.
15.       /* Open the input and output files.    */
16.       inp = fopen("b:distance.dat", "r");
17.       outp = fopen("b:distance.out", "w");
18.
19.       /* Get and echo the distance in miles. */
20.       fscanf(inp, "%lf", &miles);
21.       fprintf(outp, "The distance in miles is %.2f.\n", miles);
22.
23.       /* Convert the distance to kilometers. */
24.       kms = KMS_PER_MILE * miles;
25.
26.       /* Display the distance in kilometers. */
27.       fprintf(outp, "That equals %.2f kilometers.\n", kms);
28.
29.       /* Close files. */
30.       fclose(inp);
31.       fclose(outp);
32.
33.       return (0);
34. }
```

Read input from a file

Write the result into a file

Contents of input file `distance.dat`

```
112.0
```

Contents of output file `distance.out`

```
The distance in miles is 112.00.
That equals 180.21 kilometers.
```

A Program with Syntax Errors

```
221 /* Converts distances from miles to kilometers. */
222
223 #include <stdio.h>          /* printf, scanf definitions    */
266 #define KMS_PER_MILE 1.609 /* conversion constant          */
267
268 int
269 main(void)
270 {
271       double kms
272
273       /* Get the distance in miles. */
274       printf("Enter the distance in miles> ");
***** Semicolon added at the end of the previous source line

275       scanf("%lf", &miles);
***** Identifier "miles" is not declared within this scope
***** Invalid operand of address-of operator

276
277       /* Convert the distance to kilometers. */
278       kms = KMS_PER_MILE * miles;
***** Identifier "miles" is not declared within this scope

279
280       /* Display the distance in kilometers. * /
281       printf("That equals %f kilometers.\n", kms);
282
283       return (0);
284 }
***** Unexpected end-of-file encountered in a comment
***** "}" inserted before end-of-file
```

Syntax error occurs when the code violates grammar rules of C and is detected by the compiler.

A Program with a Run-Time Error

Run-time error occurs when the program directs the computer to perform an illegal operation (e.g., divide by zero).

```
111 #include <stdio.h>
262
263 int
264 main(void)
265 {
266         int    first, second;
267         double temp, ans;
268
269         printf("Enter two integers> ");
270         scanf("%d%d", &first, &second);
271         temp = second / first;
272         ans = first / temp;
273         printf("The result is %.3f\n", ans);
274
275         return (0);
276 }

Enter two integers> 14 3
Arithmetic fault, divide by zero at line 272 of routine main
```

temp=0

divide by zero

A Common Error with Carriage Return

Suppose the user input "2003" and press enter key.
Then input "BMC" and press enter key.

```
1.  int
2.  main(void)
3.  {
4.        char first, middle, last; /* input - 3 initials           */
5.        int pennies, nickels;  /* input - count of each coin type */
6.        int dimes, quarters;   /* input - count of each coin type */
7.        int change;              /* output - change amount       */
8.        int dollars;             /* output - dollar amount       */
9.        int total_cents;         /* total cents                  */
10.       int year;                /* current year                 */
11.
12.       /* Get the current year.                                  */
13.       printf("Enter the current year and press return> ");
14.       scanf("%d", &year);
15.
16.       /* Get the program user's initials.
17.       printf("Type in 3 initials and press return> ");
18.       scanf("%c%c%c", &first, &middle, &last);
19.       printf("Hello %c%c%c, let's check your coins' value
20.              first, middle, last, year);
21.       ...
```

Read "2003"

Read "\n", "B", "M" instead of "B", "M", "C"

A Common Error That Produces Incorrect Results Due to & Omission

scanf does not know where to store the value entered by the user, and just use the original value stored in first and second.

```
1.  #include <stdio.h>
2.
3.  int
4.  main(void)
5.  {
6.        int    first, second, sum;
7.
8.        printf("Enter two integers> ");
9.        scanf("%d%d", first, second); /* ERROR!! should be  &first, &second */
10.       sum = first + second;
11.       printf("%d + %d = %d\n", first, second, sum);
12.
13.       return (0);
14. }

Enter two integers> 14   3
5971289 + 5971297 = 11942586
```

Common Programming Errors

- **Syntax Errors -** this occurs when your code violates one or more grammar rules of C.
- **Run-Time Errors -** these are detected and displayed by the computer during the execution of a program.
- **Undetected Errors -** many execution errors may not prevent a C program from running to completion, but they may simply lead to incorrect results.
- **Logic Errors -** these occur when a program follows a faulty algorithm.
- **Debugging -** Finding bugs/errors in the program.

Run-time error

- During the computer execution, the computer detects the program is performing an illegal operation, such as dividing a number by 0.

Run-Time Errors

- Run-time errors are detected and displayed by the computer during the execution of a program.
- A run-time error occurs when the program directs the computer to perform an illegal operation, such as dividing a number by zero.
- When a run-time errors occurs, the computer will stop executing your program and will display a diagnostic message
  - This message may indicate the line where the error was detected.

```
111 #include <stdio.h>
262
263 int
264 main(void)
265 {
266         int     first, second;
267         double temp, ans;
268
269         printf("Enter two integers> ");
270         scanf("%d%d", &first, &second);
271         temp = second / first;
272         ans = first / temp;
273         printf("The result is %.3f\n", ans);
274
275         return (0);
276 }

Enter two integers> 14 3
Arithmetic fault, divide by zero at line 272 of routine main
```

Undetected errors

- The program can finish execution, but may simply get an incorrect results. Thus, it is essential for you to predict the results.
  - E.g. input of a mixture of characters and numeric data

Undetected Errors

- Many execution errors may not prevent a C program from running to completion, but they may simply lead to incorrect results.
- It is essential that you predict the results your program should produce and verify that the actual output is correct.
- A very common source of incorrect results in C programs is the input of a mixture of character and numeric data.
  - These errors can be avoided if the programmer always keeps in mind the scanf's different treatment of %c and and %d/%lf placeholders.
- These may also occur if you make a mistake about the evaluation order of an arithmetic expression with multiple operators.

Logic errors

- Caused by the faulty algorithms. They are very difficult to detect. To prevent logic errors, you must carefully check your algorithm before the implementation.

Logic Errors

- Logic errors occur when a program follows a faulty algorithm.
- Because logic errors usually do not cause run-time errors and do not display error messages, they are difficult to detect.
- The only sign of a logic error may be incorrect program output.
- You can detect logic errors by testing the program thoroughly, comparing its output to calculated results.

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 lifetime cost of a piece of software goes to maintenance.
  - Hardly any software is maintained for its whole life by the original author.
  - Program that follow the typical conventions are more readable and allow engineers to understand the code more quickly and thoroughly.
- Check your text book and **some useful links** page for some directions.

White Spaces

- The complier 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 Examples

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;
}
```

Other Styles Concerns

- Properly comment your code
- Give variables sensible names
- Prompt the user when you want to input data
- Display things in a way that looks good
  - Insert new lines to make your information more readable.
  - Format numbers in a way that makes sense for the application

Bad Programming practices

- 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 (e.g. Test case results are different than expected, program branch never executed, borderline case not tested etc.)