Arithmetic Expressions Lesson #1 Outline

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A Less Simple C Program #1

```
/*
 ************************************************
 *** Program: my_add                          ***
 *** Author: Henry Neeman (hneeman@ou.edu)    ***
 *** Course: CS 1313 010 Spring 2024          ***
 *** Lab: Sec 014 Fridays 3:00pm              ***
 *** Description: Input two integers, compute ***
 *** their sum and output the result.         ***
 ************************************************
 */
#include <stdio.h>

int main ()
{ /* main */
   /*
    ***************************
    *** Declaration Section ***
    ***************************
    *
    *****************************
    * Named Constant Subsection *
    *****************************
    */
    const int program_success_code =  0;
   /*
    *****************************
    * Local Variable Subsection *
    *****************************
    *
    * addend: the addend value that the user inputs.
    * augend: the augend value that the user inputs.
    * sum: the sum of the addend and the augend,
    *   which is output.
    */
    int addend, augend, sum;
```

Continued on the next slide.

A Less Simple C Program #2

```
/*
 *************************
 *** Execution Section ***
 *************************
 *
 ***********************
 * Greeting Subsection *
 ***********************
 *
 * Tell the user what the program does.
 */
 printf("I'll add a pair of integers.\n");
/*
 ********************
 * Input subsection *
 ********************
 *
 * Prompt the user to input the addend & augend.
 */
 printf("What pair of integers do you want to add?\n");
/*
 * Input the integers to be added.
 */
 scanf("%d %d", &addend, &augend);
```

Continued on the next slide.

A Less Simple C Program #3

```
   /*
    **************************
    * Calculation Subsection *
    **************************
    *
    * Calculate the sum.
    */
    sum = addend + augend;
   /*
    *********************
    * Output Subsection *
    *********************
    *
    * Output the sum.
    */
    printf("The sum of %d and %d is %d.\n",
        addend, augend, sum);
    return program_success_code;
} /* main */
```

The statement as a whole is an **assignment statement**.

The stuff to the right of the single equals sign is an ***arithmetic expression***.

A Less Simple C Program #4

```
#include <stdio.h>

int main ()
{ /* main */
    const int program_success_code =  0;
    int addend, augend, sum;

    printf("I'll add a pair of integers.\n");
    printf("What pair of integers do you want to add?\n");
    scanf("%d %d", &addend, &augend);
    sum = addend + augend;
    printf("The sum of %d and %d is %d.\n",
        addend, augend, sum);
    return program_success_code;
} /* main */
```

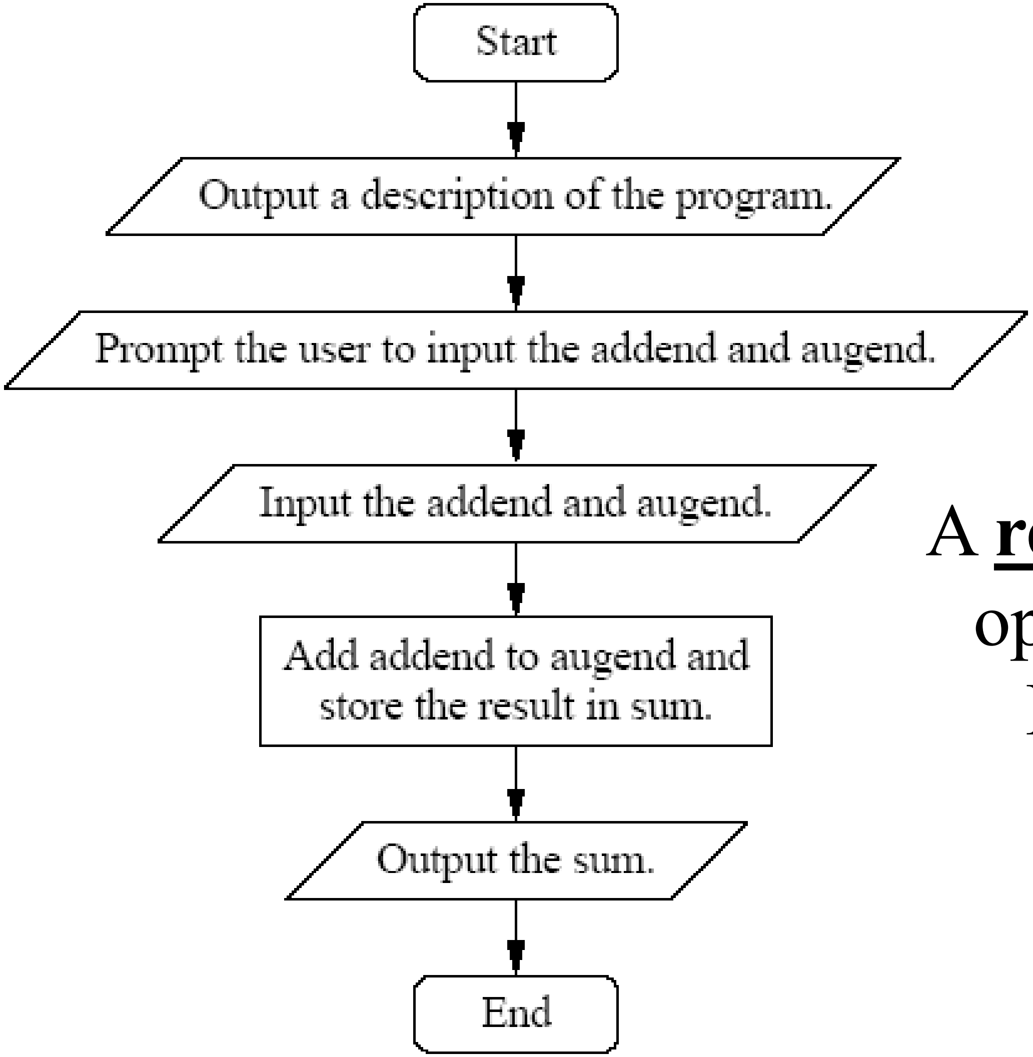
The statement as a whole is an **assignment statement**.

The stuff to the right of the single equals sign is an ***arithmetic expression***.

A Less Simple C Program: Compile & Run

```
% gcc -o my_add my_add.c
% my_add
I'll add a pair of integers.
What pair of integers do you want to add?
5 7
The sum of 5 and 7 is 12.
% my_add
I'll add a pair of integers.
What two integers do you want to add?
1593
09832
The sum of 1593 and 9832 is 11425.
```

Flowchart for `my_add.c`


Start
Output a description of the program.
Prompt the user to input the addend and augend.
Input the addend and augend.
Add addend to augend and store the result in sum.
Output the sum.
End

A **rectangle** denotes an operation other than I/O or branching (for example, calculation).

Named Constant Example Program

```
% cat circlecalc.c
#include <stdio.h>
int main ()
{ /* main */
    const float pi                   = 3.1415926;
    const float diameter_factor      = 2.0;
    const int   program_success_code = 0;
    float radius, circumference, area;
    printf("I'm going to calculate a circle's\n");
    printf(" circumference and area.\n");
    printf("What's the radius of the circle?\n");
    scanf("%f", &radius);
    circumference = pi * radius * diameter_factor;
    area = pi * radius * radius;
    printf("The circumference is %f\n", circumference);
    printf(" and the area is %f.\n", area);
    return program_success_code;
} /* main */
% gcc -o circlecalc circlecalc.c
% circlecalc
I'm going to calculate a circle's
 circumference and area.
What's the radius of the circle?
5
The circumference is 31.415924
 and the area is 78.539810.
```

Named Constant Example Program

```
% cat circlecalc.c
#include <stdio.h>
int main ()
{ /* main */
    const float pi                    = 3.1415926;
    const float diameter_factor       = 2.0;
    const int   program_success_code = 0;
    float radius, circumference, area;

    printf("I'm going to calculate a circle's\n");
    printf(" circumference and area.\n");
    printf("What's the radius of the circle?\n");
    scanf("%f", &radius);
    circumference = pi * radius * diameter_factor;
    area = pi * radius * radius;
    printf("The circumference is %f\n", circumference);
    printf(" and the area is %f.\n", area);
    return program_success_code;
} /* main */
% gcc -o circlecalc circlecalc.c
% circlecalc
I'm going to calculate a circle's
 circumference and area.
What's the radius of the circle?
5
The circumference is 31.415924
 and the area is 78.539810.
```

1997 Tax Program with Named Constants

```
% cat tax1997_named.c
#include <stdio.h>

int main ()
{ /* main */
    const float standard_deduction   = 4150.0;
    const float single_exemption     = 2650.0;
    const float tax_rate             =    0.15;
    const int   tax_year             = 1997;
    const int   program_success_code =    0;
    float income, tax;

    printf("I'm going to calculate the federal income tax\n");
    printf("  on your %d income.\n", tax_year);
    printf("What was your %d income in dollars?\n", tax_year);
    scanf("%f", &income);
    tax = (income - (standard_deduction + single_exemption)) * tax_rate;
    printf("The %d federal income tax on $%2.2f\n", tax_year, income);
    printf("  was $%2.2f.\n", tax);
    return program_success_code;
} /* main */
% gcc -o tax1997_named tax1997_named.c
% tax1997_named
I'm going to calculate the federal income tax
  on your 1997 income.
What was your 1997 income in dollars?
20000
The 1997 federal income tax on $20000.00
  was $1980.00.
```

What is an Expression? #1

```
a + b - c * d / e % f – (398 + g) * 5981 / 15 % h
```

In programming, an ***expression*** is a combination of:

- ***Operands***
- ***Operators***
- **Parentheses**: `(    )`

Not surprisingly, an expression in a program can look very much like an expression in math (though not necessarily identical). This is on purpose.

NOTE: In C, the only characters you can use for parenthesizing are **actual parentheses** (unlike in math, where you can also use square brackets and curly braces.)

What is an Expression? #2

```
a + b - c * d / e % f – (398 + g) * 5981 / 15 % h
```

In programming, an ***expression*** is a combination of:

- ***Operands***, such as:
  - Literal constants
  - Named constants
  - Variables
  - ***Function invocations*** (which we’ll discuss later)
- ***Operators***
- **Parentheses**: `(   )`

What is an Expression? #3

```
a + b - c * d / e % f – (398 + g) * 5981 / 15 % h
```

In programming, an ***expression*** is a combination of:

- ***Operands***
- ***Operators***, such as:
  - Arithmetic Operators
  - Relational Operators
  - Logical Operators
- **Parentheses**: `(    )`

What is an Expression? #4

```
a + b - c * d / e % f – (398 + g) * 5981 / 15 % h
```

In programming, an ***expression*** is a combination of:

- ***Operands***
- ***Operators***, such as:
  - Arithmetic Operators
    - Addition: +
    - Subtraction: –
    - Multiplication: *
    - Division: /
    - ***Modulus*** (remainder): `%` (only for `int` operands)
  - Relational Operators
  - Logical Operators
- **Parentheses**: `(` `)`

What is an Expression? #5

```
a + b - c * d / e % f – (398 + g) * 5981 / 15 % h
```

In programming, an ***expression*** is a combination of:

- ***Operands***
- ***Operators***, such as:
  - Arithmetic Operators
  - Relational Operators
    - Is Equal: ==
    - Not Equal: !=
    - Less Than: <
    - Less Than or Equal To: <=
    - Greater Than: >
    - Greater Than or Equal To: >=
  - Logical Operators
- **Parentheses**: ( )

What is an Expression? #6

```
a + b - c * d / e % f – (398 + g) * 5981 / 15 % h
```

In programming, an ***expression*** is a combination of:

- ***Operands***
- ***Operators***, such as:
  - Arithmetic Operators
  - Relational Operators
  - Logical Operators
    - ***Negation*** (NOT): `!`
    - ***Conjunction*** (AND): `&&`
    - ***Disjunction*** (OR): `||`
- **Parentheses**: `(` `)`

←We'll learn about these later.

What is an Arithmetic Expression? #1

An ***arithmetic expression*** (also called a ***numeric expression***) is a combination of:

- ***Numeric operands***
- ***Arithmetic Operators***
- **Parentheses**: ( )

What is an Arithmetic Expression? #2

An ***arithmetic expression*** (also called a ***numeric expression***) is a combination of:

- ***Numeric operands***, such as:
  - `int` & `float` literal constants (**BAD BAD BAD**)
  - `int` & `float` named constants (**GOOD**)
  - `int` & `float` variables
  - `int`-valued & `float`-valued ***function invocations***
- ***Arithmetic Operators***
- **Parentheses**: `(    )`

What is an Arithmetic Expression? #3

An ***arithmetic expression*** (also called a ***numeric expression***) is a combination of:

- ***Numeric operands***
- ***Arithmetic Operators***, such as:
  - Identity: `+`
  - Negation: `-`
  - Addition: `+`
  - Subtraction: `-`
  - Multiplication: `*`
  - Division: `/`
  - ***Modulus*** (remainder): `%` (only for `int` operands)
- **Parentheses**: `(    )`

Arithmetic Expression Examples

```
x
+x
-x
x + y
x - y
x * y
x / y
x % y
x + y - (z % 22) * 7 / cos(theta)
```

Unary & Binary Arithmetic Operations

Arithmetic operations come in two varieties: ***unary*** and ***binary***.

A ***unary operation*** is an operation that has only one operand. For example:

```
-x
```

Here, the **operand** is `x`, the **operator** is the minus sign, and the **operation** is negation.

A ***binary operation*** uses two operands. For example:

```
y + z
```

Here, the **operands** are `y` and `z`, the **operator** is the plus sign, and the **operation** is addition.

Arithmetic Operations

Operation	Kind	Operator	Usage	Value
Identity	Unary	+ none	+x x	Value of x Value of x
Negation	Unary	-	-x	Additive inverse of x
Addition	Binary	+	x + y	Sum of x and y
Subtraction	Binary	-	x - y	Difference between x and y
Multiplication	Binary	*	x * y	Product of x times y (i.e., x • y)
Division	Binary	/	x / y	Quotient of x divided by y (i.e., x ÷ y)
Modulus (int only)	Binary	%	x % y	Remainder of x divided by y (that is, x - ⌊x ÷ y⌋ • y)

Structure of Arithmetic Expressions #1

An arithmetic expression can be long and complicated. For example:

```
a + b - c * d / e % f
```

Terms and **operators** can be mixed together in almost limitless variety, but they must follow the rule that a unary operator has a term immediately to its right and a binary operator has terms on both its left and its right:

```
-a + b - c * d / e % f – (398 + g) * 5981 / 15 % h
```

Parentheses can be placed around any unary or binary ***subexpression***:

```
((-a) + b - c) * d / e % f – ((398 + g) * 5981 / 15) % h
```

Structure of Arithmetic Expressions #2

Putting a term in **parentheses** may change the value of the expression, because a term inside parentheses will be **calculated first**.

For example:

`a + b * c` is evaluated as

“multiply `b` by c, then add `a`,” but

`(a + b) * c` is evaluated as

“add `a` and `b`, then multiply by `c`”

Note: As a general rule, you **cannot** put two operators in a row (but we’ll see exceptions, sort of).

Jargon: `int`-valued & `float`-valued Expressions

An ***`int`-valued expression*** is an expression that, when it is evaluated, has an `int` result.

A ***`float`-valued expression*** is an expression that, when it is evaluated, has a `float` result.

Precedence Order

In the absence of parentheses that explicitly state the order of operations, the ***order of precedence*** (also known as the ***order of priority***) is:

- **first**: multiplication and division, left to right, and then
- **second**: addition, subtraction, identity and negation, left to right.

After taking into account the above rules, the expression as a whole is evaluated left to right.

More broadly: **PEMDAS** (parentheses, exponentiation, multiplication and division, addition and subtraction – but C doesn’t have an exponentiation operator).

Precedence Order Examples

- `1 -  2 - 3  = -1 -   3  = ` **`-4`** but
  `1 - (2 - 3) =  1 - (-1) =  ` **`2`**
- ` 1 + 2  * 3 + 4 = 1 + 6 + 4 = 7 + 4 = ` **`11`** but
  `(1 + 2) * 3 + 4 = 3 * 3 + 4 = 9 + 4 = ` **`13`**
- `24 /  2 * 4  = 12 * 4 = ` **`48`** but
  `24 / (2 * 4) = 24 / 8 =  ` **`3`**
- ` 5 + 4  %  6 / 2  = 5 + 4 / 2     = 5 + 2 = ` **`7`** but
  ` 5 + 4  % (6 / 2) = 5 + 4 % 3     = 5 + 1 = ` **`6`** but
  `(5 + 4) % (6 / 2) = 9 % (6 / 2) = 9 % 3 = ` **`0`**

Rule of Thumb: If you can’t remember the precedence order of the operations, use lots of parentheses.

But **DON’T** overdo your use of parentheses, because then your code would be “write only” (unreadable).

Precedence Order Example: `int` #1

```
#include <stdio.h>

int main ()
{ /* main */
    printf("1 -  2 - 3  = %d\n", 1 -  2 - 3);
    printf("1 - (2 - 3) = %d\n", 1 - (2 - 3));
    printf("\n");
    printf(" 1 + 2  * 3 + 4 = %d\n",  1 + 2  * 3 + 4);
    printf("(1 + 2) * 3 + 4 = %d\n", (1 + 2) * 3 + 4);
    printf("\n");
    printf("24 /  2 * 4  = %d\n", 24 /  2 * 4);
    printf("24 / (2 * 4) = %d\n", 24 / (2 * 4));
    printf("\n");
    printf(" 5 + 4  %  6 / 2  = %d\n",  5 + 4  %  6 / 2);
    printf(" 5 + 4  % (6 / 2) = %d\n",  5 + 4  % (6 / 2));
    printf("(5 + 4) % (6 / 2) = %d\n", (5 + 4) % (6 / 2));
} /* main */
```

Notice that a `printf` statement **CAN** output the value of an expression (but that's usually **NOT RECOMMENDED**).

Precedence Order Example: `int` #2

```
% gcc -o int_expressions int_expressions.c
% int_expressions
1 -  2 - 3  = -4
1 - (2 - 3) = 2

 1 + 2  * 3 + 4 = 11
(1 + 2) * 3 + 4 = 13

24 /  2 * 4  = 48
24 / (2 * 4) = 3

 5 + 4  %  6 / 2  = 7
 5 + 4  % (6 / 2) = 6
(5 + 4) % (6 / 2) = 0
```

Precedence Order Example: `float` #1

```
#include <stdio.h>

int main ()
{ /* main */
    printf("1.0 -  2.0 - 3.0  = %f\n", 1.0 -  2.0 - 3.0);
    printf("1.0 - (2.0 - 3.0) = %f\n", 1.0 - (2.0 - 3.0));
    printf("\n");
    printf(" 1.0 + 2.0  * 3.0 + 4.0 = %f\n",
         1.0 + 2.0  * 3.0 + 4.0);
    printf("(1.0 + 2.0) * 3.0 + 4.0 = %f\n",
        (1.0 + 2.0) * 3.0 + 4.0);
    printf("\n");
    printf("24.0 /  2.0 * 4.0  = %f\n", 24.0 /  2.0 * 4.0);
    printf("24.0 / (2.0 * 4.0) = %f\n", 24.0 / (2.0 * 4.0));
} /* main */
```

Again, notice that a `printf` statement **CAN** output the value of an expression (but that’s usually **NOT RECOMMENDED**).

Precedence Order Example: `float` #2

```
% gcc -o real_expressions real_expressions.c
% real_expressions
1.0 -  2.0 - 3.0  = -4.000000
1.0 - (2.0 - 3.0) = 2.000000

 1.0 + 2.0  * 3.0 + 4.0 = 11.000000
(1.0 + 2.0) * 3.0 + 4.0 = 13.000000

24.0 /  2.0 * 4.0  = 48.000000
24.0 / (2.0 * 4.0) = 3.000000
```