

**Introduction to Computer Engineering
0702111**

**1. Introduction and C
Fundamentals**

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www.e4t.net/intro

**Designing & Documenting
Programs**

To understand, analyze a problem statement and develop an algorithm to solve the problem, we use program development techniques (flow-charts, pseudo-code, Algorithms, etc.):

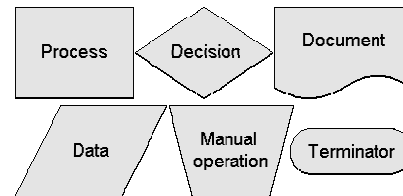
- 1. Structured Programming:** Major steps in structured programming include:
 1. Define the problem;
 2. Identify input, output, and processes;
 3. Design algorithm; AND / OR Develop flowchart, pseudo-code, etc.;

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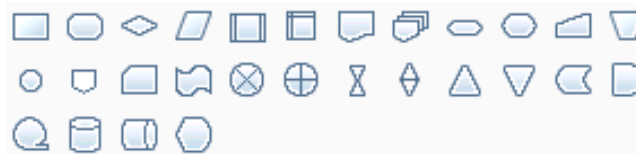
4. Code the program -- write the program;
5. Test the program --run it;
6. Debug the program (fix errors if any);
7. Document completed program (final pseudo-code, flowchart, print chart, etc.).

2. Flow Charts:

1. A flow chart is defined as a pictorial representation describing a procedure;



1. Provides people (Developers, programmers, etc.) with a common language or symbolic reference point; (Use: MS Visio)



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3. An algorithm is a formula or set of steps for solving a particular problem;

1. A clear set of rules; and
2. Have a clear stopping point.
3. Algorithms can be expressed in any language, from natural languages like English or French or Hindi to programming languages like QBASIC, C, etc.
4. **Example:** Add Two numbers, display both numbers and the sum:

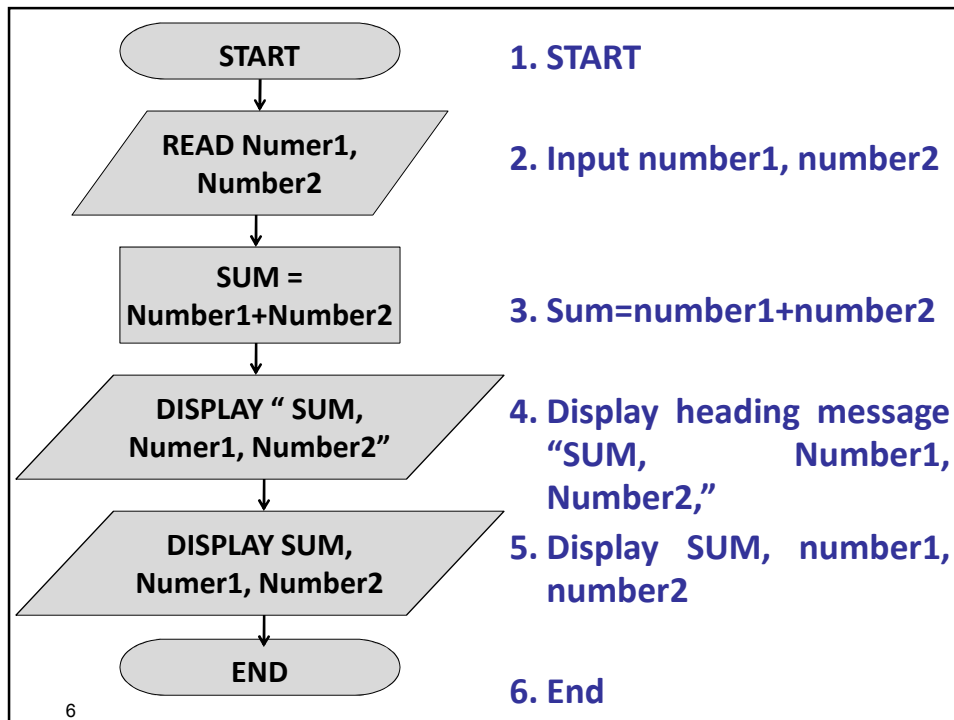
1. **START**
2. **Input number1, number2**
3. **Sum = number1 + number2**
4. **Display heading message "Number1, Number2, Sum"**
5. **Display number1, number2, Sum**

- 4 6. **End**

5. Pseudo-code:

1. An outline of a program or algorithm, written in a form that can easily be converted into real programming statements;
2. E.g. the pseudo-code for a bubble sort routine might be written:
while not at end of list
compare adjacent elements
if second is greater than first
switch them
get next two elements
if elements were switched
repeat for entire list

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5. Pseudo-code: An outline of a program or algorithm, written in a form that can easily be converted into real programming statements;

1. Example: The pseudo-code to add two numbers might be written:

Start

Input number1, number2

Sum = number1 + number2

Display heading message "Number1, Number2, Sum"

Display number1, number2, Sum

End

2. Can not be compiled nor executed, and there are no real formatting or syntax rules.

6. Caution: *Never write your program before either Algorithming, flowcharting or pseudo-coding it.*

Develop a C program to Compute the Volume and Dimensional weight of a box?

1. Analysis:

1) Outputs: *Box_Volume, Box_D_Weight;*

2) Inputs:

Height, length, width;

3) Processing:

1) Box_Volume = height * length * width;

2) Box_D_Weight = (Box_Volume + 165)/166;

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2. Algorithm:

1. Start;

2. Input height, length, width;

3. Compute:

1. $Box_Volume = height * length * width;$

2. $Box_D_Weight = (Box_Volume + 165)/166;$

4. Output Box_Volume, Box_D_Weight;

5. End.

3. DRY RUN The Algorithm;

4. Code the algorithm in C:

```
/*A C program to compute the Volume & Dimensional  
weight Dimensional weight of a box*/  
/* STEP 1: START PART */  
#include <stdio.h>  
main()  
{  
    int height, length, width, Box_Volume,  
    Box_D_Weight; /*declaring variables*/  
    /* STEP 2: Reading Data*/  
    printf("Enter height of box: ");  
    scanf("%d", &height);  
    printf("Enter length of box: ");  
    scanf("%d", &length);
```

```

printf("Enter width of box: ");
scanf("%d", &width);
/* STEP 3: Computation */
Box_Volume = height * length * width;
Box_D_Weight = (Box_Volume + 165) / 166;
/* step 4 OUTPUT*/
printf ("Dimensions: %d x %d x %d \n", length,
width, height);
printf ("Volume (cubic inches): %d \n",
Box_Volume); /* printing expression */
printf ("Dimensional weight (pounds): %d \n",
Box_D_Weight);
/* STEP 5 END*/
return 0;
}

```

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The C Language

- Currently, the most commonly-used language
- Very portable: compilers exist for virtually every processor
- Easy-to-understand compilation
- Produces efficient code
- Fairly concise
- C is a **compiled language**

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Benefits of learning C

- You will be able to read and write code for a large number of platforms -- everything from microcontrollers to the most advanced scientific systems can be written in C, and many modern operating systems are written in C.
- The jump to the object oriented C++ language becomes much easier. C++ is an extension of C, and it is nearly impossible to learn C++ without learning C first.

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C History

- Developed between 1969 and 1973 along with Unix
- Due mostly to Dennis Ritchie
- Designed for systems programming
 - Operating systems
 - Utility programs
 - Compilers
 - Filters



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- Original machine (DEC PDP-11) was very small
 - 24K bytes of memory, 12K used for operating system
- Written when computers were big, capital equipment
 - Group would get one, develop new language, OS



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'Hello World' in C

```
#include <stdio.h>
main()
{
    printf("Hello, world!\n");
    return 0;
}
```

#include → C preprocessor command that lets user includes the code from another file (such as a library)

stdio.h → standard input/output library

#include <stdio.h> → allows you to use code from the standard input/output library that contains ***printf*** function

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- ***main*** → Every program must have a *function* named **main** which contains statements enclosed in braces { and }
- ***printf*** → A function from the standard I/O library that **prints a string** (f stands for formatted)
- ***ln*** → A **new line character**. The **\n** inside the string indicates a new line
- Every *function* must return a value. **Main** is a *function* and returns a value taken by the operating system as the program terminates
- ***return 0*** → Used to signal **OS** that the program terminated normally

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Compiling & Linking

- *Programs in C must be:*
 1. **Preprocessor** → Handles all commands that begin with **#** (directives);
 2. **Compiled** → Compiler translates the source code (program) into machine code producing **.obj** file;
 3. **Linked** – the linker combines the **obj** file with additional necessary code from library functions (like ***printf***) to produce final executable file.

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IDE's to write C programs

- Many compilers and code editors are available and can be used to test your C programs, these are some popular examples:
 - Microsoft Visual C++
 - BloodShed Dev C++
 - Code::Blocks
- Links to download them are available on course website.

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General C program!

```
# directives  
main()  
{  
  statements  
}
```

- **Statements** → Commands that are carried out as program runs;
 - *printf* is a *call* statement displaying *string* on screen:
 - *printf ("hello"); /* These are comments */*
 - *printf ("world! \n"); /* Can go any where in a C */*
- Statements end with a *semicolon (;)*

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Some definitions

“Hello, World!\n”

- **Character** → A single letter, number, punctuation mark, etc.
- **String** → Series of characters grouped together;
- Some special kinds of *characters* exist:
 - *lf* – tab character;
 - *ln* – new line character.

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Important Basic Rules for C

- Statements of code end with a **semicolon ;**
- **Strings** are enclosed inside **double-quotes “ ”**
- **Functions** start and end with curly brackets **{ }**
- White space (Blank Space) doesn't matter;
- C language is **case sensitive**
- Some names are **keywords** (such as **int** and **float**) and can't be used as **identifiers**

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Question:

- Try writing a short C program to display a 5x5 square of asterisks.

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Types & Variables

- Most programming languages perform calculations; thus **need** a way to **store data temporarily** during program execution
- These **storage locations** are called ***variables***.
- Variable names are ***identifiers*** that contain letters, digits and underscores and must begin with a letter or underscore
- **C** has various data types such as:
 - ***int*** → Integer type, such as 45,
 - ***char*** → Character type, such as 'a', and
 - ***float*** → Floating-point type, such as 3.14159;
 - ***bool*** → Boolean type; ***true*** or ***false***.

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Declaration of Variables

- **Variables** → Must be declared before they are used;
- **Declaration** → Precedes *statements* in the main program;
- Have to declare the type of variables (*int or float*) before declarations

```
main()  
{  
    declaration & assignments  
    statements  
}
```

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Variable Declaration Examples

```
int hours_worked;
```

```
float hourly_rate, gross_pay, net_pay;
```

Assignments Example

Variables can be given a value by means of assignments

```
height = 12;
```

```
width = 8;
```

```
length = 1;
```

```
volume = height * width * length;
```

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Printing a Variable Value

- Use:
 - *printf* function to print the value of a *variable*
 - *%d* is a placeholder that works for *int*
 - *%f* is a placeholder that works for *float*
 - **char** (single character values, discussed later) uses *%c*
 - **character strings** (arrays of characters, discussed later) use *%s*
 - *%.2f* displays a float value of 2 digits after the decimal points (34.21);

```
printf ("Hours worked: %d \n", hours_worked);  
printf ("Hourly Rate: $%.2f \n", hourly_rate);
```

%d and *%.2* are placeholders indicating where the value of *hours_worked* & *hourly_rate* to be filled during printing

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Example on Printing Variables

- To print out the line: *Profit: \$2267.14*

```
printf ("Profit: $%.2f \n", profit);
```
- To print:

```
printf ("Height: %d Length: %d \n",  
height, length);
```
- *%f* by default displays 6 digits after the decimal point
- *%.nf* – forces *%f* to display *n* digits after the decimal point

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Develop a C program to Compute the Volume and Dimensional weight (see textbook p18) of a 12"x10"x8" box?

1. Analysis:

1. Outputs: *Box_Volume, Box_D_Weight;*

2. Inputs: Known data:

1. *height = 8;*

2. *length = 12;*

3. *width = 10;*

3. Processing:

1. *Box_Volume = height * length * width;*

2. *Box_D_Weight = (Box_Volume + 165) / 166;*

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2. Algorithm:

1. Start;

2. Assign:

1. *height = 8;*

2. *length = 12;*

3. *width = 10;*

3. Compute:

1. *Box_Volume = height * length * width;*

2. *Box_D_Weight = (Box_Volume + 165) / 166;*

4. Output *Box_Volume, Box_D_Weight;*

5. End.

3. RUN The Algorithm;

4. Code the algorithm in C:

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```

/*A C program to compute the Volume &
   Dimensional weight Dimensional weight of a
   12"x10"x8" box */
/* STEP 1: START PART */
#include <stdio.h>
main()
{
    int height, length, width, Box_Volume,
    Box_D_Weight; /*declaring variables*/
    /* STEP 2: Assingment */
    height = 8;    /* assigning values to
                    variables */

    length = 12;
    width = 10;

```

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```

/ * STEP 3: Computation */
Box_Volume = height * length * width;
Box_D_Weight = (Box_Volume + 165) / 166;
//answer will be 'truncated'
/* step 4 OUTPUT */
printf ("Dimensions: %d x %d x %d \n",
        length, width, height);
printf ("Volume (cubic inches): %d \n",
        Box_Volume); // printing expression)
printf ("Dimensional weight (pounds): %d \n",
        Box_D_Weight);
/* STEP 5 END*/
return 0;
}

```

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2/12 @11

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Reading a user Input

- To obtain an input from users: Use *scanf* function
- *scanf* and *printf* requires a *format string* with which we specify the format these functions will take
- **To read an:**
 - *int*: Use “%d”
 - `scanf (“%d”, &hours_worked);`
 - *float*: Use “%f”
 - `scanf (“%f”, &hourly_rate);`
- “%d” reads an **integer value** and **stores** it into the **integer variable** *hours_worked*;

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Develop a C program to Compute the Volume and Dimensional weight of a box?

1. Analysis:

1. Outputs: *Box_Volume, Box_D_Weight;*

2. Inputs:

1. *Height, length, width;*

3. Processing:

1. *Box_Volume = height * length * width;*

2. *Box_D_Weight = (Box_Volume + 165) / 166;*

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2. Algorithm:

1. Start;

2. Assign:

1. *Input height, length, width;*

3. Compute:

1. *Box_Volume = height * length * width;*

2. *Box_D_Weight = (Box_volume + 165) / 166;*

4. *Output Box_Volume, Box_D_Weight;*

5. End.

3. RUN The Algorithm;

4. Code the algorithm in C:

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```

/* A C program to compute the Volume &
   Dimensional weight Dimensional weight
   of a box */
/* STEP 1: START PART */
#include <stdio.h>
main()
{
    int height, length, width, Box_Volume,
    Box_D_Weight; /* declaring variables */
    /* STEP 2: Reading Data*/
    printf("Enter height of box: ");
    scanf("%d", &height);
    printf("Enter length of box: ");
    scanf("%d", &length);

```

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```

    printf("Enter width of box: ");
    scanf("%d", &width);
    /* STEP 3: Computation */
    Box_Volume = height * length * width;
    Box_D_Weight = (Box_Volume + 165) / 166;
    /* STEP 4 OUTPUT */
    printf ("Dimensions: %d x %d x %d \n",
            length, width, height);
    printf ("Volume (cubic inches): %d \n",
            Box_Volume);
    printf ("Dimensional weight (pounds): %d
            \n", Box_D_Weight);
    /* STEP 5 END*/
    return 0;
}

```

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Question:

- Try writing a C program that takes 3 integer values, calculates and prints their summation and average.

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Macro Definitions

- **Constants are:**
 - Values that do not change;
 - Defined in C using *macro definitions*:
 - #define label constant***
 - #define DAYS_PER_WEEK 7***
 - ***#define*** → Preprocessor directive similar to ***#include***
 - ***Every*** time compiler sees ***DAYS_PER_WEEK*** the numeric value ***7*** is substituted;
 - ***macro definition***, by convention: → Uses UPER-CASE letters
- **No semicolon** at end of ***#define***
- **Constants are preferable over literals.**

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Develop a C program that Converts a Fahrenheit temperature value to a Celsius one using a macro definition?

Solution:

- 1) Analysis (Define: Output(s), Input(s), Processes;**
- 2) Develop the Algorithm;**
- 3) Dry RUN the algorithm;**
- 4) Convert the algorithm to C code:**

>>

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```
/* A C program that Converts a Fahrenheit temperature value to a
   Celsius one */

#include <stdio.h>

#define FREEZING_PT 32.0 /* define label FREEZING_PT to
   represent constant 32 */
#define SCALE_FACTOR (5.0 / 9.0)
/* compiler would put the whole expression in the constant name
   place below, 5/9 will lead to 0 (truncation) */
int main()
{
    float fahrenheit, celsius;
    printf("Enter Fahrenheit temperature: ");
    scanf("%f", &fahrenheit);
    celsius = (fahrenheit - FREEZING_PT) *
              SCALE_FACTOR;
    printf("Celsius equivalent: %.1f\n", celsius);
    return 0;
}
```

Revision, examples, and more

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printf/scanf

- You need to include the header file `stdio.h` to be able to use them.
- `scanf` scans user input and match them with the formatted string.
- **Example (Q6 p43):**
Books are identified by an international standard book number (ISBN) such as 0-393-30375-6 the first part represents the language (0 for English 3 for German..etc) the next group represents the publisher, the third represents the book, and the last digit is a check digit, write a C programme to break an ISBN entered by the user.

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```

#include <stdio.h>
main()
{
    int language, publisher, book_number, check_digit;
    printf("Enter ISBN: ");
    scanf("%d-%d-%d-%d", &language, &publisher,
        &book_number, &check_digit);
    printf("Language: %d\n", language);
    printf("Publisher: %d\n", publisher);
    printf("Book number: %d\n", book_number);
    printf("Check digit: %d\n", check_digit);
    /* The four printf calls can be combined as
       follows:
    printf("Language: %d\nPublisher: %d\nBook number:
        %d\nCheck digit: %d\n",
        language, publisher, book_number, check_digit);
    */
    return 0;
}
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```

Place holders/string formatting

- **%d** – displays integer in decimal form (base 10).
- **%e** – displays a floating point number in exponential form.
Ex:
 printf("The number is %15.3e\n", 123.45678); Will show "The number is 1.235e+002"
 Note the reserved 15 places reserved for the whole number, and the 3 digits shown to the right of the point.
- **%f** – for floating points.
- **%g** – displays a floating-point number in exponential format or fixed decimal format.

More on placeholders

- %nd → n spaces reserved
- %.nd → n leading zeros OR d decimal digits
- %% for % character
- %e → floating point in exponential (scientific) format, ex. 3.912e+1
- %E → same but with capital e, ex. 3.912E+1
- %g → the shortest of %e and %f
- %G → same with capital (e if any)
- %d or %i → signed decimal integer
- %u → unsigned decimal integer
- %p → pointer (address) in hex, more about pointers later
- %x → unsigned hex integer, ex. 37fa
- %X → same with capitals, ex. 37FA
- %o → octal

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Another example:

- Q6 p83:
Write a program that asks the user for a 24-hour time, then displays it in 12-hour form, be careful not to display 12:00 as 0:00, Ex:
Enter a 24-hour time: 21:11
Equivalent 12-hour time: 9:11 PM

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```

#include <stdio.h>
main()
{
    int hours, minutes;
    printf("Enter a 24-hour time: ");
    scanf("%d:%d", &hours, &minutes);
    /* assumption: midnight entered as 00:00, valid times
       are 00:00-23:59 */
    printf("Equivalent 12-hour time: ");
    if (hours == 0)
        printf("12:%.2d AM\n", minutes);
    else if (hours < 12)
        printf("%d:%.2d AM\n", hours, minutes);
        /* We used "%.2d" instead of "%d:%2d" to get 9:09
           AM for something like 9:9 instead of 9: 9 AM */
    else if (hours == 12)
        printf("%d:%.2d PM\n", hours, minutes);
    else
        printf("%d:%.2d PM\n", hours % 12, minutes);
    return 0;
} 49

```

Boolean variables

- We used to evaluate logical expressions as integers.
- Usually you can also define boolean variables using `bool` keyword.

• Ex:

```

#include <stdio.h>
int main()
{
    bool even;
    int number=99;
    if (number%2==0)
        even=true;
    else
        even=false;
    if (even==true)
        printf("The number is even\n");
    else
        printf("The number is NOT even\n");
    return 0;
}

```

- Can you think of shorter implementation?

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Mathematical Notes:

- math.h
 - sqrt() function.

```
int x=4;
printf("The square root of %d is %f.\n", x, sqrt(x));
```

–tan/cos/sin

- Angles in radians.

–Power.

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- Example:

```
#include <stdio.h>
#include <math.h>
main()
{
    int x=4;
    printf("The square root of %d is %f.\n",
    x, sqrt(x));
    float ang=3.14/2; //Angles should be in
    radians
    printf("The sine of %f is %f.\n", ang,
    sin(ang));
    return 0;
}
```

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Questions:

- Write a C program to calculate the 2 roots of a quadratic equation.
- Develop a concise C program to convert an area from m^2 to $inch^2$

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- **Exercises:**

- 1) Code the algorithm/flowchart shown on [slide 6](#) (sum of 2 numbers);
- 2) Develop a **C** program to **Calculate** the **Net Pay** of a worker. The program should **accept the number of worked hours** and **the hourly rate** from the user?

Hint: *A sample run of the program would be:*

Simple Payroll Program:

Enter the number of hours worked: 21
Enter the hourly rate of pay: 12.5
Hours Worked: 21
Hourly Rate: \$12.50
Gross Pay: \$262.50
FICA Deduction: \$20.08
Net Pay: \$242.42

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Solved Exercise 1 Calculating Net Pay

Here is a sample run of the program:

Simple Payroll Program:

Enter the number of hours worked: 21

Enter the hourly rate of pay: 12.5

Hours Worked:	21
Hourly Rate:	\$12.50
Gross Pay:	\$262.50
FICA Deduction:	\$20.08
Net Pay:	\$242.42

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