

INTRODUCTION

CS10003: PROGRAMMING AND DATA STRUCTURES



Course Materials

Slides available at <http://cse.iitkgp.ac.in/pds/current>

More materials available at <http://cse.iitkgp.ac.in/pds>

Books:

1. Programming with C, Byron Gottfried
 2. The C Programming Language, Brian W Kernighan, Dennis M Ritchie
 3. Programming in ANSI C, E. Balaguruswamy
 4. Data Structures, S. Lipschutz, Schaum's Outline Series
- ... and many more options

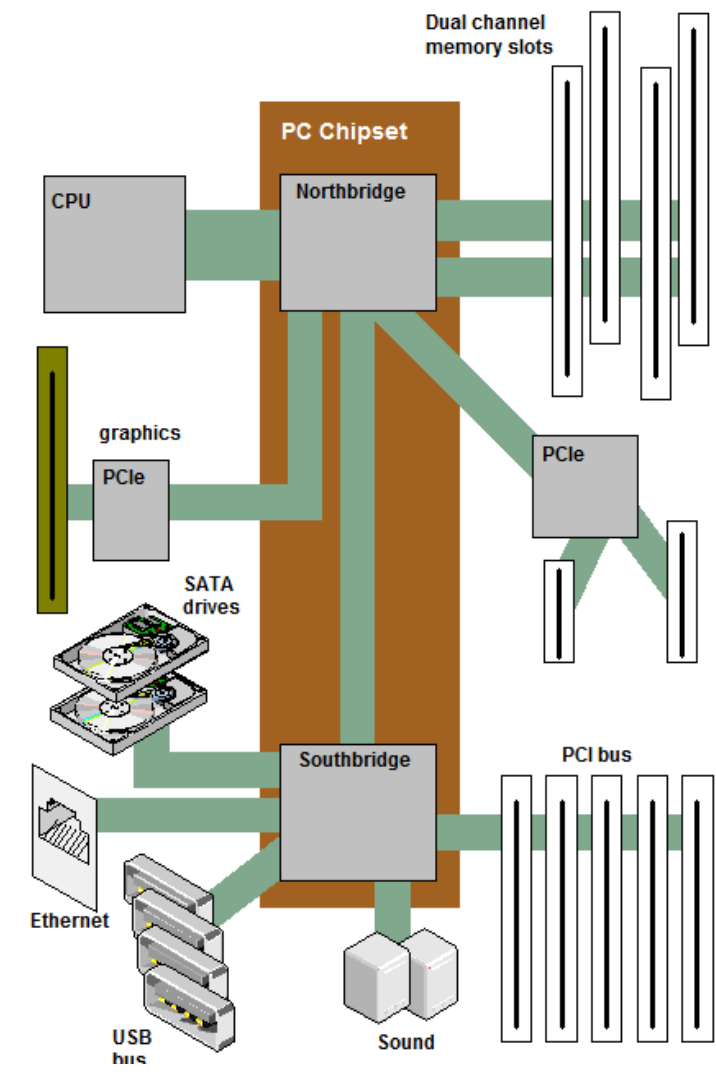
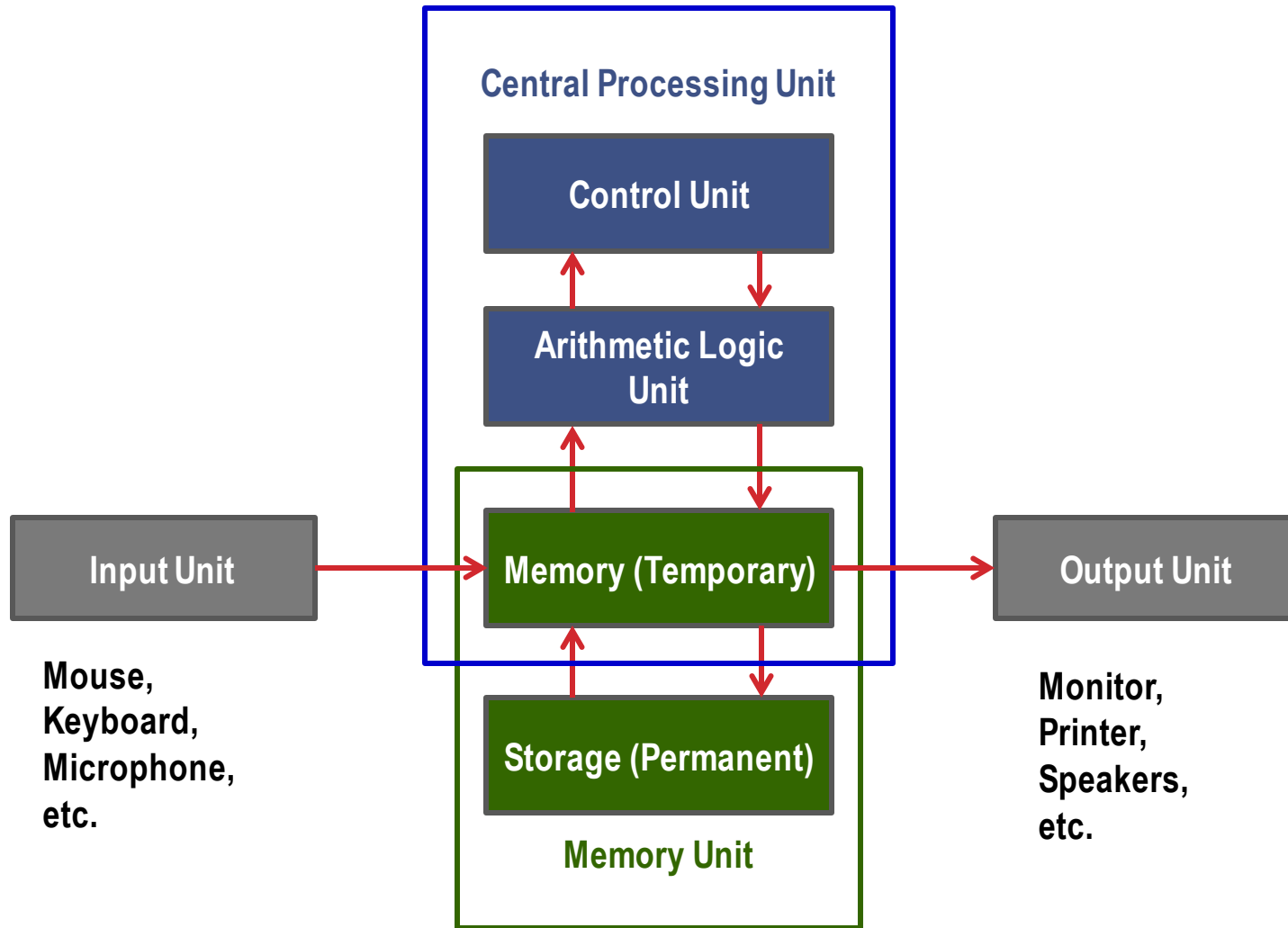
Teachers and Class Timings

- **Section 1, 2**
 - **Monday (3-4:55 pm), Tuesday (3-3:55 pm)**
 - **Teacher: Prof. Debasis Samanta (DSM)**
- **Section 3, 4**
 - **Monday (3-4:55 pm), Tuesday (3-3:55 pm)**
 - **Teacher: Prof. Pallab Dasgupta (PDG)**
- **Section 5, 6**
 - **Monday (3-4:55 pm), Tuesday (3-3:55 pm)**
 - **Teacher: Prof. Partha Pratim Chakraborty (PPC)**
- **Section 7, 8**
 - **Wednesday (10-10:55 am), Thursday (9-9:55 am), Friday (11-11:55 am)**
 - **Teacher: Prof. Somindu Chaya Ramanna (SCR)**
- **Section 9, 10**
 - **Wednesday (10-10:55 am), Thursday (9-9:55 am), Friday (11-11:55 am)**
 - **Teacher: Prof. Sudebkumar Prasant Pal (SPP)**

Evaluation Plan (Tentative)

- **2 short tests (about 1 hour each)**
 - **Around 30-40% of the marks**
- **2 long tests (about 2 hours each)**
 - **Around 70-60% of the marks**

Basic Components in a Computer



Programming and Software

- A computer needs to be **programmed** to do tasks
- **Programming** is the process of writing instructions in a **language** that can be understood by the computer so that a desired task can be performed by it
- **Program**: sequence of instructions to do a task, computer processes the instructions sequentially one after the other
- **Software**: programs for doing tasks on computers



Three steps in writing programs

Step 1: Write the program in a high-level language (in your case, C)

Step 2: Compile the program using a C compiler

Step 3: Run the program (as the computer to execute it)

Binary Representation

The decimal number system we use is base-10

- 10 digits, from 0 to 9, Positional weights $10^0, 10^1, 10^2, \dots$ from right to left for integers
- Example: $723 = 3 \times 10^0 + 2 \times 10^1 + 7 \times 10^2$

Numbers are represented inside computers in the base-2 system (Binary Numbers)

- Only two symbols/digits 0 and 1
- Positional weights of digits: $2^0, 2^1, 2^2, \dots$ from right to left for integers
- Example: 1101 in binary = $(1 \times 2^0) + (0 \times 2^1) + (1 \times 2^2) + (1 \times 2^3) = 13$ in decimal

Binary Numbers

Dec	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000

Binary Numbers

Dec	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000

Binary to Decimal Conversion

$$101011 \rightarrow 1x2^5 + 0x2^4 + 1x2^3 + 0x2^2 + 1x2^1 + 1x2^0 = 43$$

$$(101011)_2 = (43)_{10}$$

$$111001 \rightarrow 1x2^5 + 1x2^4 + 1x2^3 + 0x2^2 + 0x2^1 + 1x2^0 = 57$$

$$(111001)_2 = (57)_{10}$$

$$10100 \rightarrow 1x2^4 + 0x2^3 + 1x2^2 + 0x2^1 + 0x2^0 = 20$$

$$(10100)_2 = (20)_{10}$$

Bits and Bytes

- **Bit** – a single 1 or 0
- **Byte** – 8 consecutive bits
 - 2 bytes = 16 bits
 - 4 bytes = 32 bits
- **Maximum integer that can be represented**
 - in 1 byte = 255 (=11111111)
 - In 4 bytes = 4294967295 (= 32 1's)
- **Number of integers that can be represented in 1 byte = 256 (the integers 0, 1, 2, 3,.....255)**

Fundamentals of C



First C program – print on screen

```
#include <stdio.h>

int main()
{
    printf ("Hello, World! \n");
    return 0;
}
```

Output

Hello, World!

A Simple C program

```
#include <stdio.h>
int main()
{
    int x, y, sum, max;

    scanf("%d%d", &x, &y);

    sum = x + y;
    if (x > y) max = x;
        else max = y;

    printf ("Sum = %d\n", sum);
    printf ("Larger = %d\n", max);
    return 0;
}
```

When you run the program



Output after you type 15 and 20

```
15 20
Sum = 35
Larger = 20
```

Structure of a C program

- A collection of **functions** (we will see what they are later)
- Exactly one special function named **main()** must be present. Program always starts from there.
 - **Until we study functions in detail, this is the only function your programs will have for now**
- Each function has statements for variable declarations, assignment, condition check, looping etc.
- Statements are executed one by one in order

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

```
int main()
```

```
{
```

```
    int x, y, sum, max;
```

```
    scanf("%d%d", &x, &y);
```

```
    sum = x + y;
```

```
    if (x > y)
```

```
        max = x;
```

```
    else
```

```
        max = y;
```

```
    printf ("Sum = %d\n", sum);
```

```
    printf ("Larger = %d\n", max);
```

```
    return 0;
```

```
}
```

main function

Declaration statement

Input statement

Assignment statements

Control statement

Output statements

Return statement

Writing a C program

- You will have to understand what different statements do to decide which you should use in what order to solve your problem
- There is a fixed format ("syntax") for writing each statement and other things. Need to remember the syntax.
 - Do not question why you have to type exactly like this, you just have to or it is not a C program!!
 - Compiler will give error if your typed program does not match required C syntax
- There are other rules to follow

Things you will see in a C program (we will look at all these one by one)

- **Variables**
- **Constants**
- **Expressions (Arithmetic, Logical, Assignment)**
- **Statements (Declaration, Assignment, Control (Conditional/Branching, Looping))**
- **Arrays**
- **Functions**
- **Structures**
- **Pointers**

The C Character Set

The C language alphabet

- Uppercase letters 'A' to 'Z'
- Lowercase letters 'a' to 'z'
- Digits '0' to '9'
- Certain special characters:

!	#	%	^	&	*	()
-	_	+	=	~	[]	\
	;	:	'	"	{	}	,
.	<	>	/	?			

whitespace characters (space, tab, ...)

A C program should not contain anything else

Variables

- Very important concept for programming
- An entity that has a value and is known to the program by a name
- Can store any temporary result while executing a program
- Can have only one value assigned to it at any given time during the execution of the program
- The value of a variable can be changed during the execution of the program

Variables are stored in memory

Memory is a list of consecutive storage locations, each having a unique address

A variable is like a **bin**

- The contents of the bin is the **value** of the variable
- The variable name is used to refer to the value of the variable
- A variable is mapped to a location of the memory, called its **address**

Example

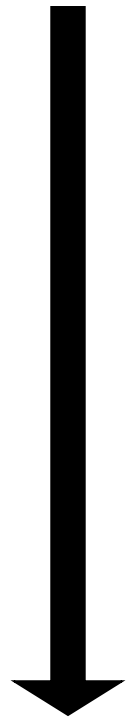
```
#include <stdio.h>
int main()
{
    int x;
    int y;

    x=1;
    y=3;

    printf("x = %d, y= %d\n", x, y);
    return 0;
}
```

Variables in Memory

Instruction sequence



$X = 10$

$X = 20$

$X = X + 1$

$X = X * 5$

Memory

X

?

(may contain whatever value at the beginning)

Variables in Memory

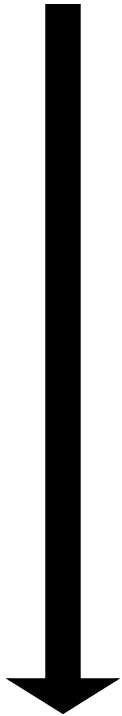
Instruction sequence

$X = 10$

$X = 20$

$X = X + 1$

$X = X * 5$



after executing $X = 10$

X

Memory

10

Variables in Memory

Instruction sequence

$X = 10$

$X = 20$

$X = X + 1$

$X = X * 5$

Memory

X

20

after executing $X = 20$

Variables in Memory

Instruction sequence

$X = 10$

$X = 20$

$X = X + 1$

$X = X * 5$

Memory

X

21

after executing $X = X + 1$

Variables in Memory

Instruction sequence

$X = 10$

$X = 20$

$X = X + 1$

$X = X * 5$

Memory

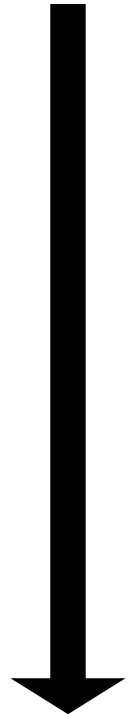
X

105

after executing $X = X * 5$

Variables in Memory

Instruction sequence



$X = 20$

$Y = 15$

$X = Y + 3$

$Y = X / 6$

Memory

X

?

(may contain whatever value at the beginning)

Y

?

(may contain whatever value at the beginning)

Variables in Memory

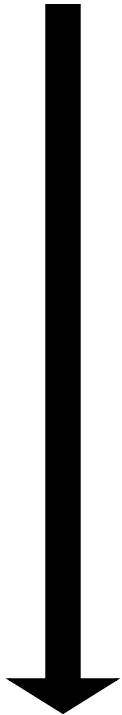
Instruction sequence

$X = 20$

$Y = 15$

$X = Y + 3$

$Y = X / 6$



after executing $X = 20$

Memory

X

20

Y

?

Variables in Memory

Instruction sequence

$X = 20$

$Y = 15$

$X = Y + 3$

$Y = X / 6$

Memory

X

20

Y

15

after executing $Y = 15$

Variables in Memory

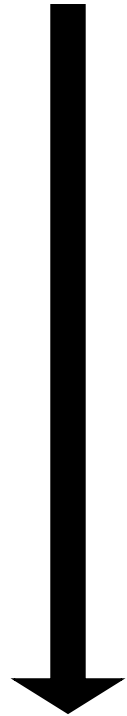
Instruction sequence

$X = 20$

$Y = 15$

$X = Y + 3$

$Y = X / 6$



Memory

X

18

Y

15

after executing $X = Y + 3$

Variables in Memory

Instruction sequence

$X = 20$

$Y = 15$

$X = Y + 3$

$Y = X / 6$

Memory

X

18

Y

3

after executing $Y = X / 6$

Data Types

- Each variable has a **type**, indicates what type of values the variable can hold
- Four common data types in C (there are others)
 - **int** - can store integers (usually 4 bytes)
 - **float** - can store single-precision floating point numbers (usually 4 bytes)
 - **double** - can store double-precision floating point numbers (usually 8 bytes)
 - **char** - can store a character (1 byte)

Rules and good practices

- First rule of variable use: **Must declare a variable** (specify its **type** and **name**) before using it anywhere in your program
- All variable declarations should ideally be at the beginning of the `main()` or other functions
 - There are exceptions, we will see later
- A value can also be assigned to a variable at the time the variable is declared.

```
int speed = 30;  
char flag = 'y';
```

Variable Names

- Sequence of letters and digits
- First character must be a letter or ‘_’
- No special characters other than ‘_’
- No blank in between
- Names are **case-sensitive** (max and Max are two different names)

- Examples of valid names:

i rank1 MAX max Min class_rank

- Examples of invalid names:

a's fact rec 2sqrt class,rank

More Valid and Invalid Identifiers

Valid identifiers

X

abc

simple_interest

a123

LIST

stud_name

Empl_1

Empl_2

_avg_empl_salary

Invalid identifiers

10abc

my-name

“hello”

simple interest

(area)

%rate

C Keywords

- Used by the C language, cannot be used as variable names

- Examples:

int, float, char, double, main, if else, for, while, do, struct, union, typedef, enum, void, return, signed, unsigned, case, break, sizeof,.....

- There are others, see textbook...

Example 1

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

```
int main()
```

```
{
```

```
    int x, y, sum;
```

← Three integer type variables declared

```
    scanf("%d%d",&x,&y);
```

```
    sum = x + y;
```

← Values assigned

```
    printf( "%d plus %d is %d\n", x, y, sum );
```

```
    return 0;
```

```
}
```

Example 2

```
#include <stdio.h>
int main()
{
    float x, y;           /* Two floating point variables declared */
    int d1, d2 = 10;     /* Here integer variable d2 is initialized to 10, can be changed later */

    scanf("%f%f%d",&x, &y, &d1);
    printf( "%f plus %f is %f\n", x, y, x + y);
    printf( "%d minus %d is %d\n", d1, d2, d1 - d2);

    return 0;
}
```

Read-only Variables

- Variables whose values can be initialized during declaration, but cannot be changed after that
- Declared by putting the **const** keyword in front of the declaration
- Storage allocated just like any variable
- Used for variables whose values need not be changed
 - Prevents accidental change of the value

Correct

```
int main() {  
    const int LIMIT = 10;  
    int n;  
    scanf("%d", &n);  
    if (n > LIMIT) printf("Out of limit");  
    return 0;  
}
```

Incorrect: Limit changed

```
int main() {  
    const int Limit = 10;  
    int n;  
    scanf("%d", &n);  
    Limit = Limit + n;  
    printf("New limit is %d", Limit);  
    return 0;  
}
```

Constants

- Integer constants
 - Consists of a sequence of digits, with possibly a plus or a minus sign before it
 - Embedded spaces, commas and non-digit characters are not permitted between digits
- Floating point constants
- Two different notations:
 - Decimal notation: 25.0, 0.0034, .84, -2.234
 - Exponential (scientific) notation
 - 3.45e23, 0.123e-12, 123e2

e means "10 to the power of"

Contd.

- **Character constants**
 - **Contains a single character enclosed within a pair of single quote marks.**
 - **Examples :: '2', '+', 'Z'**
- **Some special backslash characters**
 - **'\n' new line**
 - **'\t' horizontal tab**
 - **'\'' single quote**
 - **'\"' double quote**
 - **'\\' backslash**
 - **'\0' null**

Typical Size of Data Types

char – 1 byte

int – 4 bytes

float – 4 bytes

double – 8 bytes

- “Typical”, because some of them vary depending on machine/OS type
- Therefore never use the values (1, 4, 8) directly, use the `sizeof()` operator given
 - `sizeof(char)` will give 1, `sizeof(int)` will give 4 and so on ... as per your PC/Laptop

Input: scanf function

- Performs input from keyboard
- It requires a format string and a list of variables into which the value received from the keyboard will be stored
- format string = individual groups of characters (usually ‘%’ sign, followed by a conversion character), with one character group for each variable in the list

```
int a, b;
```

```
float c;
```

Variable list (note the **&** before
each variable name)

```
scanf("%d%d%f", &a, &b, &c);
```

Format string

Commonly used conversion characters

c for char type variable

d for int type variable

f for float type variable

lf for double type variable

Examples

```
scanf ("%d", &size) ;
```

- Reads one integer from keyboard into an **int** type variable named **size**

```
scanf ("%c", &nextchar) ;
```

- Reads one character from keyboard into a **char** type variable named **nextchar**

```
scanf ("%f", &length) ;
```

- Reads one floating point (real) number from keyboard into a **float** type variable named **length**

```
scanf ("%d%d", &a, &b);
```

- Reads two integers from keyboard, the first one in an **int** type variable named **a** and the second one in an **int** type variable named **b**

Important

- `scanf()` will wait for you to type the input from the keyboard
- You must type the same number of inputs as the number of %'s in the format string
- **Example: if you have `scanf("%d%d",...)`, then you must type two integers (in same line or different lines), otherwise `scanf()` will just wait and the next statement will not be executed**

Reading a single character

- A single character can be read using `scanf` with `%c`
- It can also be read using the `getchar()` function

```
char c;  
c = getchar();
```

- Program waits at the `getchar()` line until a character is typed, and then reads it and stores it in `c`

- What happens here?

```
char a, b;  
printf("Enter the first character:\n");  
a = getchar( );  
printf("Enter the second character:\n");  
b = getchar( );
```

- You may encounter a situation where the computer does not wait for reading the second character. Why?

Output: printf function

- Performs output to the standard output device (typically defined to be the screen)
- It requires a format string in which we can specify:
 - The text to be printed out
 - Specifications on how to print the values
`printf ("The number is %d\n", num);`
 - The format specification `%d` causes the value listed after the format string to be embedded in the output as a decimal number in place of `%d`
 - Output will appear as: **The number is 125**

General syntax of printf()

```
printf (format string, arg1, arg2, ..., argn);
```

- format string refers to a string containing formatting information and data types of the arguments to be output
- the arguments arg1, arg2, ... represent list of variables/expressions whose values are to be printed
- The conversion characters are the same as in scanf

- **Examples:**

```
printf ("Average of %d and %d is %f", a, b, avg);
```

```
printf ("Hello \nGood \nMorning \n");
```

```
printf ("%3d %3d %5d", a, b, a*b+2);
```

```
printf ("%7.2f %5.1f", x, y);
```

- Many more options are available for both printf and scanf – read from the book

More Examples

(Explain the outputs to test if you understood format strings etc.)

More print

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

Output

```
Hello, World! Hello
World!
```

Some more print

```
#include <stdio.h>

int main()
{
    printf ("Hello, World! \n");
    printf ("Hello \n World! \n");
    printf ("Hell\no \t World! \n");
    return 0;
}
```

Output

```
Hello, World!
Hello
World!
Hell
o      World!
```

Some more print

```
#include <stdio.h>
int main()
{
    float f1, f2;
    int x1, x2;
    printf("Enter values for f1 and f2: \n");
    scanf("%f%f", &f1, &f2);
    printf("Enter values for x1 and x2: \n");
    scanf("%d%d", &x1, &x2);
    printf("f1 = %f, f2 = %5.2f\n", f1, f2);
    printf("x1 = %d, x2 = %10d\n", x1, x2);
    return 0;
}
```

Output

```
Enter values for f1 and f2:
23.5 14.326
Enter values for x1 and x2:
54 7
f1 = 23.500000, f2 = 14.33
x1 = 54, x2 = 7
```

Can you explain why
14.326 got printed as
14.33?

Some more print

```
#include <stdio.h>

int main()
{
    char c1, c2;
    scanf("%c%c", &c1, &c2);
    printf("%c%c", c1, c2);
    return 0;
}
```

Output

```
ab
ab
```

What about this?

```
#include <stdio.h>

int main()
{
    char c1, c2;
    scanf("%c%c", &c1, &c2);
    printf("%c%c", c1, c2);
    return 0;
}
```

Output

```
a b
a
```

Can you explain why only 'a' was printed this time, even though it is the same program as in the last slide? Note the difference from the last slide carefully. Also note that two characters were read this time also, or scanf would have waited

Practice Problems

Write C programs to

1. Read two integers and two floating point numbers, each in a separate `scanf()` statement (so 4 `scanf`'s) and print them with separate `printf` statements (4 `printf`'s) with some nice message
2. Repeat 1, but now read all of them in a single `scanf` statement and print them in a single `printf` statement
3. Repeat 1 and 2 with other data types like `double` and `char`
4. Repeat 1 and 2, but now print all real numbers with only 3 digits after the decimal point
5. Read 4 integers in a single `scanf` statement, and print them (using a single `printf` statement) in separate lines such that the last digit of each integer is exactly 10 spaces away from the beginning of the line it is printed in (the 9 spaces before will be occupied by blanks or other digits of the integer). Remember that different integers can have different number of digits
6. Repeat 5, but now the first integer of each integer should be exactly 8 spaces away from the beginning of the line it is printed in.