# Number System
# Number Representation

# Topics to be Discussed

- How are numeric data items actually stored in computer memory?
- How much space (memory locations) is allocated for each type of data?
  - int, float, char, etc.
- How are characters and strings stored in memory?

# Number System :: The Basics

- We are accustomed to using the so-called *decimal number system*.
  - Ten digits :: 0,1,2,3,4,5,6,7,8,9
  - Every digit position has a weight which is a power of 10.
  - Base or radix is 10.
- Example:

$234 = 2 \times 10^2 + 3 \times 10^1 + 4 \times 10^0$

$250.67 = 2 \times 10^2 + 5 \times 10^1 + 0 \times 10^0 + 6 \times 10^{-1} + 7 \times 10^{-2}$

# Binary Number System

- Two digits:
  - 0 and 1.
  - Every digit position has a weight which is a power of 2.
  - *Base* or *radix* is 2.
- Example:

$$110 = 1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$$

$$101.01 = 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 + 0 \times 2^{-1} + 1 \times 2^{-2}$$

# Counting with Binary Numbers

Values with more than two states require multiple bits

A collection of two bits has four possible states:

**00,01,10,11**

**a collection of eight possible states:**

**000,001,010,011,100,101,110,111**

A collection of n bits has 2n possible states

0
1
10
11
100
101
110
111
1000
.

# Multiplication and Division with base

- Multiplication with 10 (decimal system)

  435 x 10 = 4350

- Multiplication with 10 (=2 ) (binary system)

  1101 x 10 = 11010

- Division by 10 (decimal system)

  435 / 10 = 43.5

- Division by 10 (=2) (binary system)

  1101 / 10 = 110.1

*Left Shift and add zero at right end*

*Right shift and drop right most digit or shift after decimal point*

# Adding two bits

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 10

carry

Carries

| | | | | | |
|---|---|---|---|---|---|
| | 1 | 1 | 1 | 0 | |
| | | 1 | 0 | 1 | 1 |
| + | | 1 | 1 | 1 | 0 |
| | 1 | 1 | 0 | 0 | 1 |

# Binary addition: Another example

The initial carry
in is implicitly 0

| | | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 1 | 0 | 0 | | (Carries) |
| | | 1 | 1 | 0 | 1 | |
| + | | 1 | 1 | 0 | 0 | |
| | 1 | 1 | 0 | 0 | 1 | (Sum) |

most significant
bit (MSB)

least significant
bit (LSB)

# Binary-to-Decimal Conversion

- Each digit position of a binary number has a weight.
  - Some power of 2.
- A binary number:

$$B = b_{n-1}\, b_{n-2} \,\ldots\ldots b_1\, b_0 \,.\, b_{-1}\, b_{-2} \,\ldots\ldots\, b_{-m}$$

Corresponding value in decimal:

$$D = \sum_{i=-m}^{n-1} b_i\, 2^i$$

# Examples

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

   $= 43$

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

2. $.0101 \rightarrow 0x2^{-1} + 1x2^{-2} + 0x2^{-3} + 1x2^{-4}$

   $= .3125$

   $(.0101)_2 = (.3125)_{10}$

3. $101.11 \rightarrow 1x2^2 + 0x2^1 + 1x2^0 + 1x2^{-1} + 1x2^{-2}$

   $5.75$

   $(101.11)_2 = (5.75)_{10}$

# Decimal-to-Binary Conversion

- Consider the integer and fractional parts separately.
- For the integer part,
  - Repeatedly divide the given number by 2, and go on accumulating the remainders, until the number becomes zero.
  - Arrange the remainders *in reverse order*.
- For the fractional part,
  - Repeatedly multiply the given fraction by 2.
    - Accumulate the integer part (0 or 1).
    - If the integer part is 1, chop it off.
  - Arrange the integer parts *in the order* they are obtained.

# Example 1 :: 239

| | | |
|---|---|---|
| 2 | 239 | |
| 2 | 119 | --- 1 |
| 2 | 59 | --- 1 |
| 2 | 29 | --- 1 |
| 2 | 14 | --- 1 |
| 2 | 7 | --- 0 |
| 2 | 3 | --- 1 |
| 2 | 1 | --- 1 |
| 2 | 0 | --- 1 |

$$(239)_{10} = (11101111)_2$$

# Example 2 :: 64

| | | |
|---|---|---|
| 2 | 64 | |
| 2 | 32 | --- 0 |
| 2 | 16 | --- 0 |
| 2 | 8 | --- 0 |
| 2 | 4 | --- 0 |
| 2 | 2 | --- 0 |
| 2 | 1 | --- 0 |
| 2 | 0 | --- 1 |

$(64)_{10} = (1000000)_2$

# Example 3 :: .634

$.634 \times 2 = 1.268$

$.268 \times 2 = 0.536$

$.536 \times 2 = 1.072$

$.072 \times 2 = 0.144$

$.144 \times 2 = 0.288$

:

:

$(.634)_{10} = (.10100\ldots\ldots)_2$

# Example 4 :: 37.0625

$(37)_{10} = (100101)_2$

$(.0625)_{10} = (.0001)_2$

$(37.0625)_{10} = (100101\,.\,0001)_2$

# Hexadecimal Number System

- A compact way of representing binary numbers.

- 16 different symbols (radix = 16).

| | | | | | |
|---|---|---|---|---|---|
| 0 | → | 0000 | 8 | → | 1000 |
| 1 | → | 0001 | 9 | → | 1001 |
| 2 | → | 0010 | A | → | 1010 |
| 3 | → | 0011 | B | → | 1011 |
| 4 | → | 0100 | C | → | 1100 |
| 5 | → | 0101 | D | → | 1101 |
| 6 | → | 0110 | E | → | 1110 |
| 7 | → | 0111 | F | → | 1111 |

# Binary-to-Hexadecimal Conversion

- For the integer part,
  - Scan the binary number from *right to left*.
  - Translate each group of four bits into the corresponding hexadecimal digit.
    - Add *leading* zeros if necessary.
- For the fractional part,
  - Scan the binary number from *left to right*.
  - Translate each group of four bits into the corresponding hexadecimal digit.
    - Add *trailing* zeros if necessary.

# Example

1. $(\underline{1011}\ \underline{0100}\ \underline{0011})_2 = (B43)_{16}$
2. $(\underline{10}\ \underline{1010}\ \underline{0001})_2 = (2A1)_{16}$
3. $(.\underline{1000}\ \underline{010})_2 = (.84)_{16}$
4. $(\underline{101}\,.\,\underline{0101}\ \underline{111})_2 = (5.5E)_{16}$

# Hexadecimal-to-Binary Conversion

- Translate every hexadecimal digit into its 4-bit binary equivalent.
- Examples:

$(3A5)_{16} = (\underline{0011}\ \underline{1010}\ \underline{0101})_2$

$(12.3D)_{16} = (\underline{0001}\ \underline{0010}\ .\ \underline{0011}\ \underline{1101})_2$

$(1.8)_{16} = (\underline{0001}\ .\ \underline{1000})_2$

# Some Important (number) data Types

- Unsigned integers: 0,1,2,3,4…..
- Signed integers: -3, -2, -1, 0, 1, 2, 3
- Floating point numbers:
- PI=3.14154 X $10^0$

# Unsigned Binary Numbers

- An n-bit binary number

  $B = b_{n-1}b_{n-2} \ldots . b_2b_1b_0$

  - $2^n$ distinct combinations are possible, 0 to $2^n$-1.

- For example, for n = 3, there are 8 distinct combinations.
  - 000, 001, 010, 011, 100, 101, 110, 111

- Range of numbers that can be represented

  n=8 → 0 to $2^8$-1 (255)

  n=16 → 0 to $2^{16}$-1 (65535)

  n=32 → 0 to $2^{32}$-1 (4294967295)

# Word size

- Every real computer has base word size:
  - 16 bit, 32 bit, and 64 bit
- Memory fetches are word by word
  - Even if you want 8 bit (a byte)

# Word Size

| Unsigned Integer | Binary Representation [minimum bits] | Binary Representation [8-bit word size] | Binary Representation [16-bit word size] |
|---|---|---|---|
| **3** | 11 | 00000011 | 0000000000000011 |
| **10** | 1010 | 00001010 | 0000000000001010 |
| **15** | 1111 | 00001111 | 0000000000001111 |
| **255** | 11111111 | 11111111 | 0000000011111111 |
| **256** | 100000000 | Not Possible | 0000000100000000 |
| **65536** | ?? | ?? | ?? |

# Signed Integer Representation

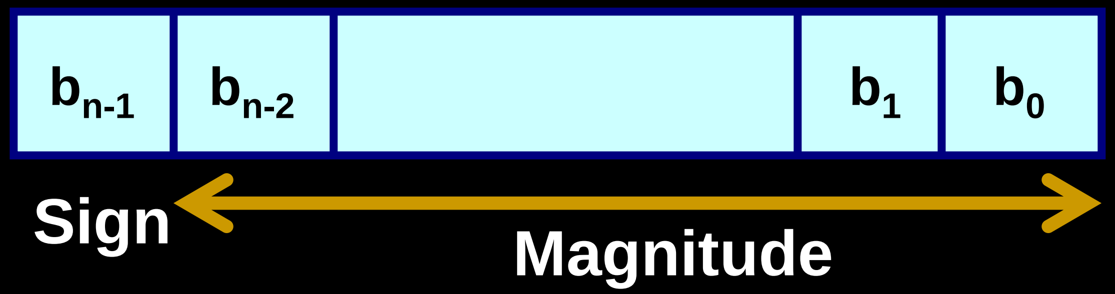
- Many of the numerical data items that are used in a program are signed (positive or negative).
- With n bits we have $2^n$ distinct values.
  - Assign about half to positive integers (1 through $2^n$ -1)
  - and another half - $2^n$ -1 through -1
  - Question:: How to represent sign?
- Three possible approaches:
  - Sign-magnitude representation
  - One’s complement representation
  - Two’s complement representation

# Sign-magnitude Representation

- For an n-bit number representation
  - The most significant bit (MSB) indicates sign

    0 → positive

    1 → negative
  - The remaining n-1 bits represent magnitude.



# Representation and ZERO

- Range of numbers that can be represented:

  Maximum :: $+ (2^{n-1} - 1)$

  Minimum :: $- (2^{n-1} - 1)$

- A problem:

  Two different representations of zero.

  +0 → 0 000....0

  -0 → 1 000....0

# Examples

| Signed Integer | Binary Representation [minimum bits] | Binary Representation [8-bit word size] | Binary Representati [16-bit word size] |
|---|---|---|---|
| **-5** | 1 101 | 10000101 | 1000000000000101 |
| **+5** | 0 101 | 00000101 | 0000000000000101 |
| **+127** | 01111111 | 01111111 | 0000000001111111 |
| **-127** | 11111111 | 11111111 | 1000000001111111 |
| **+0** | 00 | 00000000 | 0000000000000000 |
| **-0** | 10 | 10000000 | 1000000000000000 |

# Sign Magnitude Representation

- Easy to understand and encode
- One problem : two representation of 0 (-0 and +0)
- Addition of K + (-K) does not give 0

- $-5 + 5 = (1000\ 0101)_2 + (0000\ 0101)_2$
- $= (1000\ 1010)_2$
- $= (10)_{10}$

# One’s Complement Representation

- Basic idea:
  - Positive numbers are represented exactly as in sign-magnitude form.
  - Negative numbers are represented in 1’s complement form.

- How to compute the 1’s complement of a number?
  - Complement every bit of the number (1→0 and 0→1).
  - MSB will indicate the sign of the number.

    0 → positive

    1 → negative

# Example :: n=4

| | |
|---|---|
| 0000 → +0 | 1000 → -7 |
| 0001 → +1 | 1001 → -6 |
| 0010 → +2 | 1010 → -5 |
| 0011 → +3 | 1011 → -4 |
| 0100 → +4 | 1100 → -3 |
| 0101 → +5 | 1101 → -2 |
| 0110 → +6 | 1110 → -1 |
| 0111 → +7 | 1111 → -0 |

**To find the representation of -4, first note that**

**+4 = 0100**

**-4 = 1's complement of 0100 = 1011**

# One’s Complement Representation

- Range of numbers that can be represented:

  Maximum :: $+(2^{n-1} - 1)$

  Minimum :: $-(2^{n-1} - 1)$

- A problem:

  Two different representations of zero.

  +0 → 0 000….0

  -0 → 1 111….1

- Advantage of 1’s complement representation
  - Subtraction can be done using addition.
  - Leads to substantial saving in circuitry.

# Examples

| Signed Integer | Binary Representation [minimum bits] | Binary Representation [8-bit word size] | Binary Representation [16-bit word size] |
|---|---|---|---|
| -5 | 1010 | 11111010 | 1111111111111010 |
| +5 | 0 101 | 00000101 | 0000000000000101 |
| +127 | 01111111 | 01111111 | 0000000001111111 |
| -127 | 10000000 | 10000000 | 1111111110000000 |
| +0 | 00 | 00000000 | 0000000000000000 |
| -0 | 11 | 11111111 | 1111111111111111 |

# Two's Complement Representation

- Basic idea:
  - Positive numbers are represented exactly as in sign-magnitude form.
  - Negative numbers are represented in 2's complement form.

- How to compute the 2's complement of a number?
  - Complement every bit of the number (1→0 and 0→1), and then ***add one*** to the resulting number.
  - MSB will indicate the sign of the number.

    0 → positive

    1 → negative

# Example :: n=4

| | |
|---|---|
| 0000 → +0 | 1000 → -8 |
| 0001 → +1 | 1001 → -7 |
| 0010 → +2 | 1010 → -6 |
| 0011 → +3 | 1011 → -5 |
| 0100 → +4 | 1100 → -4 |
| 0101 → +5 | 1101 → -3 |
| 0110 → +6 | 1110 → -2 |
| 0111 → +7 | 1111 → -1 |

**To find the representation of, say, -4, first note that**

**+4 = 0100**

**-4 = 2's complement of 0100 = 1011+1 = 1100**

# Storage and number system in Programming

- In C
  - short int
    - 16 bits → $+(2^{15}-1)$ to $-2^{15}$
  - int
    - 32 bits → $+(2^{31}-1)$ to $-2^{31}$
  - long int
    - 64 bits → $+(2^{63}-1)$ to $-2^{63}$

# Storage and number system in Programming

- Range of numbers that can be represented:

  Maximum :: $+(2^{n-1} - 1)$

  Minimum :: $-2^{n-1}$

- Advantage:
  - *Unique representation of zero*.
  - Subtraction can be done using addition.
  - Leads to substantial saving in circuitry.

- Almost all computers today use the 2's complement representation for storing negative numbers.

# Subtraction Using Addition :: 1's Complement

- How to compute A – B ?
  - Compute the 1's complement of B (say, $B_1$).
  - Compute $R = A + B_1$
  - If the carry obtained after addition is '1'
    - Add the carry back to R (called *end-around carry*).
    - That is, $R = R + 1$.
    - The result is a positive number.

    Else
    - The result is negative, and is in 1's complement form.

# Example 1 :: 6 – 2

A = 6 (0110)
B = 2 (0010)
6 – 2 = A - B

1's complement of 2 = 1101

| | | | |
|---|---|---|---|
| 6 | :: | 0110 | A |
| -2 | :: | 1101 | $B_1$ |
| | | 1 0011 | |
| End-around carry | | 1 | R |
| | | 0100 | → +4 |

Assume 4-bit representations.

Since there is a carry, it is added back to the result.

The result is positive.

# Example 2 :: 3 – 5

1's complement of 5 = 1010

| | | | |
|---|---|---|---|
| 3 | :: | 0011 | A |
| -5 | :: | 1010 | $B_1$ |
| | | 1101 | R |

⇓

-2

**Assume 4-bit representations.**

**Since there is no carry, the result is negative.**

**1101 is the 1's complement of 0010, that is, it represents –2.**

# Subtraction Using Addition :: 2's Complement

- How to compute A – B ?
  - Compute the 2's complement of B (say, $B_2$).
  - Compute $R = A + B_2$
  - Ignore carry if it is there.
  - The result is in 2's complement form.

# Example 1 :: 6 – 2

2's complement of 2 = 1101 + 1 = 1110

| | | |
|---|---|---|
| 6 | :: | 0110 |
| -2 | :: | 1110 |
| | | 1 0100 |

**A**

$B_2$

**R**

**Ignore carry**

**+4**

# Example 2 :: 3 – 5

2’s complement of 5 = 1010 + 1 = 1011

| | | |
|---|---|---|
| 3 | :: | 0011 |
| -5 | :: | 1011 |
| | | 1110 |

↓

-2

**A**

**$B_2$**

**R**

# Example 3 :: -3 – 5

2's complement of 3 = 1100 + 1 = 1101

2's complement of 5 = 1010 + 1 = 1011

| | | |
|---|---|---|
| -3 | :: | 1101 |
| -5 | :: | 1011 |
| | | 1 1000 |

**Ignore carry**

**-8**

# Floating-point Numbers

- The representations discussed so far applies only to integers.
  - Cannot represent numbers with fractional parts.
- We can assume a decimal point before a 2’s complement number.
  - In that case, pure fractions (without integer parts) can be represented.
- We can also assume the decimal point somewhere in between.
  - This lacks flexibility.
  - Very large and very small numbers cannot be represented.

# Representation of Floating-Point Numbers

- A floating-point number F is represented by a doublet <M,E> :

  $F = M \times B^E$

  - B → exponent base (usually 2)
  - M → mantissa
  - E → exponent

  - M is usually represented in 2's complement form, with an implied decimal point before it.

- For example,

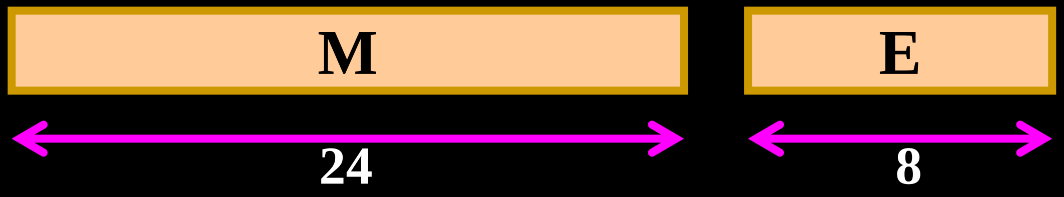
  In decimal,

  $0.235 \times 10^6$

  In binary,

  $0.101011 \times 2^{0110}$

# Example :: 32-bit representation




- M represents a 2’s complement fraction

  $1 > M > -1$

- E represents the exponent (in 2’s complement form)

  $127 > E > -128$

- Points to note:
  - The number of *significant digits* depends on the number of bits in M.
    - 6 significant digits for 24-bit mantissa.
  - The *range* of the number depends on the number of bits in E.
    - $10^{38}$ to $10^{-38}$ for 8-bit exponent.

# Floating point number: IEEE Standard 754

- Storage Layout

| | Sign | Exponent | Fraction / Mantissa |
|---|---|---|---|
| Single Precision | 1 [31] | 8 [30–23] | 23 [22–00] |
| Double Precision | 1 [63] | 11 [62–52] | 52 [51–00] |

Single: SEEEEEEE EMMMMMMM MMMMMMMM MMMMMMMM
Double: SEEEEEEE EEEEMMMM MMMMMMMM MMMMMMMM
MMMMMMMM MMMMMMMM MMMMMMMM MMMMMMMM

# IEEE Standard 754

1. The sign bit is 0 for positive, 1 for negative.
2. The exponent base is two.
3. The exponent field contains 127 plus the true exponent for single-precision, or 1023 plus the true exponent for double precision.
4. The first bit of the mantissa is typically assumed to be 1.*f*, where *f* is the field of fraction bits.

## Ranges of Floating-Point Numbers

Since every floating-point number has a corresponding, negated value (by toggling the sign bit), the ranges above are symmetric around zero.

# IEEE Standard 754

## Ranges of Floating-Point Numbers

Since every floating-point number has a corresponding, negated value (by toggling the sign bit), the ranges above are symmetric around zero.

| | Denormalized | Normalized | Approximate Decimal |
|---|---|---|---|
| Single Precision | $\pm\ 2^{-149}$ to $(1-2^{-23})\times 2^{-126}$ | $\pm\ 2^{-126}$ to $(2-2^{-23})\times 2^{127}$ | $\pm \approx 10^{-44.85}$ to $\approx 10^{38.53}$ |
| Double Precision | $\pm\ 2^{-1074}$ to $(1-2^{-52})\times 2^{-1022}$ | $\pm\ 2^{-1022}$ to $(2-2^{-52})\times 2^{1023}$ | $\pm \approx 10^{-323.3}$ to $\approx 10^{308.3}$ |

# IEEE Standard 754

There are five distinct numerical ranges that single-precision floating-point numbers are **not** able to represent:

1. Negative numbers less than $-(2-2^{-23}) \times 2^{127}$ (*negative overflow*)
2. Negative numbers greater than $-2^{-149}$ (*negative underflow*)
3. Zero
4. Positive numbers less than $2^{-149}$ (*positive underflow*)
5. Positive numbers greater than $(2-2^{-23}) \times 2^{127}$ (*positive overflow*)

# Special Values

- Zero

  $-0$ and $+0$ are distinct values
- Denormalized
  - If the exponent is all 0s, but the fraction is non-zero, then the value is a *denormalized* number, which now has an assumed leading *0* before the binary point.
  - Thus, this represents a number $(-1)^s \times 0.f \times 2^{-126}$, where $s$ is the sign bit and $f$ is the fraction.
  - For double precision, denormalized numbers are of the form $(-1)^s \times 0.f \times 2^{-1022}$.
  - From this you can interpret zero as a special type of denormalized number.

# Special Values

- Infinity

  The values $+\infty$ and $-\infty$ are denoted with an exponent of all 1s and a fraction of all 0s. The sign bit distinguishes between negative infinity and positive infinity. Being able to denote infinity as a specific value is useful because it allows operations to continue past overflow situations. *Operations with infinite values are well defined in IEEE floating point.*

- Not A Number

  The value NaN (*Not a Number*) is used to represent a value that does not represent a real number. NaN's are represented by a bit pattern with an exponent of all 1s and a non-zero fraction.

# Representation of Characters

- Many applications have to deal with non-numerical data.
  - Characters and strings.
  - There must be a standard mechanism to represent alphanumeric and other characters in memory.

- Three standards in use:
  - Extended Binary Coded Decimal Interchange Code (EBCDIC)
    - Used in older IBM machines.
  - American Standard Code for Information Interchange (ASCII)
    - Most widely used today.
  - UNICODE
    - Used to represent all international characters.
    - Used by Java.

# ASCII Code

- Each individual character is numerically encoded into a unique 7-bit binary code.
  - A total of $2^7$ or 128 different characters.
  - A character is normally encoded in a byte (8 bits), with the MSB not been used.
- The binary encoding of the characters follow a regular ordering.
  - Digits are ordered consecutively in their proper numerical sequence (0 to 9).
  - Letters (uppercase and lowercase) are arranged consecutively in their proper alphabetic order.

# Some Common ASCII Codes

‘A’ :: 41 (H) 65 (D)

‘B’ :: 42 (H) 66 (D)

………..

‘Z’ :: 5A (H) 90 (D)

‘a’ :: 61 (H) 97 (D)

‘b’ :: 62 (H) 98 (D)

………..

‘z’ :: 7A (H) 122 (D)

‘0’ :: 30 (H) 48 (D)

‘1’ :: 31 (H) 49 (D)

………..

‘9’ :: 39 (H) 57 (D)

‘(‘ :: 28 (H) 40 (D)

‘+’ :: 2B (H) 43 (D)

‘?’ :: 3F (H) 63 (D)

‘\n’ :: 0A (H) 10 (D)

‘\0’ :: 00 (H) 00 (D)

# Character Strings

- Two ways of representing a sequence of characters in memory.
  - The first location contains the number of characters in the string, followed by the actual characters.

| | | | | | |
|---|---|---|---|---|---|
| 5 | H | e | l | l | o |

  - The characters follow one another, and is terminated by a special delimiter.

| | | | | | |
|---|---|---|---|---|---|
| H | e | l | l | o | $\perp$ |

# String Representation in C

- In C, the second approach is used.
  - The '\0' character is used as the string delimiter.
- Example:

  "Hello" →

| | | | | | |
|---|---|---|---|---|---|
| H | e | l | l | o | '\0' |

- A null string "" occupies one byte in memory.
  - Only the '\0' character.

# Problem 7

Given 2 positive numbers *n* and *r*, *n*>=*r* , write a C function to compute the number of combinations(${}^{n}C_{r}$) and the number of permutations(${}^{n}P_{r}$).

Permutations formula is P(n,r)=n!/(n-r)!

Combinations formula is C(n,r)=n!/(r!(n-r)!)

# Problem 8

Scope of variable:

What is the output of the following code snippet?

```
#include <stdio.h>

int main(){
        int i = 10;
        for(int i = 5; i < 15; i++)
                printf("i is %d\n", i);
         return 0;
}
```

# Problem 9

**Scope of variable: What is the output of the following code snippet?**

```
#include <stdio.h>
int a = 20;
int sum(int a, int b) {
        printf ("value of a in sum() = %d\n",  a);
        printf ("value of b in sum() = %d\n",  b);
        return a + b;
}
int main ()
{
        int a = 10;  int b = 20;  int c = 0;
        printf ("value of a in main() = %d\n",  a);
        c = sum( a, b);
        printf ("value of c in main() = %d\n",  c);
        return 0;
```

# Problem 10

**Write a C program which display the entered number in words.**

**Example:**

**Input:**
**Enter a number: 7**

**Output:**
**Seven**

# Problem 11

**Write a C program to delete duplicate elements in an array without using another auxiliary array.**

**Example:**

**Input:**
**5 8 5 5 6 9 8 2 1 1 3 3**

**Output:**
**5 8 6 9 2 1 3**

# Problem 12

**Write a C program to print PASCAL's triangle.**

```
                1
              1   1
            1   2   1
          1   3   3   1
        1   4   6   4   1
      1   5  10  10   5   1
    1   6  15  20  15   6   1
  1   7  21  35  35  21   7   1
1   8  28  56  70  56  28   8   1
```

# Problem 13

Given 2 numbers ***a*** and ***b***, write a C program to compute the Greatest Common Divisor(GCD) of the 2 numbers.

The GCD of 2 numbers is the largest positive integer that divides the numbers without a remainder.

Example: GCD(2,8)=2;  GCD(3,7)=1

# Problem 14

Given 2 arrays of integers ***A*** and ***B*** of size ***n*** each, write a C program to calculate the dot product of the 2 arrays.

If ***A***$=[a_0, a_1, a_2,\ldots.,a_{n-1}]$ and

***B***$= [b_0, b_1, b_2,\ldots.,b_{n-1}]$,

the dot product of ***A*** and ***B*** is given by

$A.B=[a_0*b_0 + a_1*b_1 + a_2*b_2 + \ldots\ldots + a_{n-1}*b_{n-1}]$

# Problem 15

Given a non negative integer *n*, write a C function to output the decimal integer(base 10) in its binary representation (base 2).

Example: Binary representation of

| | | |
|---|---|---|
| 3 | is | 11 |
| 8 | is | 1000 |
| 15 | is | 1111 |

# Problem 16

Given two array of sorted numbers *A* and *B*, both are of arbitrary sizes, write a C function named ***merge_arrays*** that merges both the arrays in sorted order and returns the sorted array C.