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Course: COMPUTER ARCHITECTURE AND ORGANISATION (MCSE503L)

1. Discuss the history behind the development of computers with neat sketch? Identify and discuss the various digital tools to simulate the design of ALU in details?

Early History of Computer: -

One of the earliest and most well-known devices was an abacus. Then is 1822, the father of computers, Charles Babbage began developing what would be the first mechanical computer. And then in 1833 he actually designed an Analytical Engine which was a general-purpose computer. Generation of Computer: In the history of computers, we often refer to the advancements of modern computers as the generation of the computer. We are currently on the fifty generation of computers. So let us look at the important features of these five generations of computers.

Generation	Year	Electronic devices used	Types of OS and devices
First	1945 – 55	Vacuum tubes	Plug boards
Second	1955 – 1965	Transistors	Batch system
Third	1965 – 1980	Integrated Circuit (IC)	Multiprogramming
Fourth	Since 1980	Large scale integration	PC

1 st Generation: -

This was from the period of 1940 to 1955. This was when machine language was developer for the use of computer. They used vacuum tunes for the circuitry. For the purpose of memory, they used magnetic drums. These machines were complicated, large, and expensive. They were mostly reliant on batch operation systems and punch cards. As output and input devices, magnetic tape and paper tape were implemented. For example, ENIAC, UNIVAC1, EDVAC, and so on.

2 nd Generation: -

The years 1957-1963 were referred to as the “second generation of computers” at the time. In second-generation of computers, COBOL and FORTRAN are employed as assembly languages and programming languages. Here they advanced from vacuum tube to transistors. This made the computers smaller, faster and more energy-efficient. And they advanced from binary to assembly languages. For instance, IBM 1620, IBM 7094, CDC 1640, CDC 3600, and so forth.

3 rd Generation:-

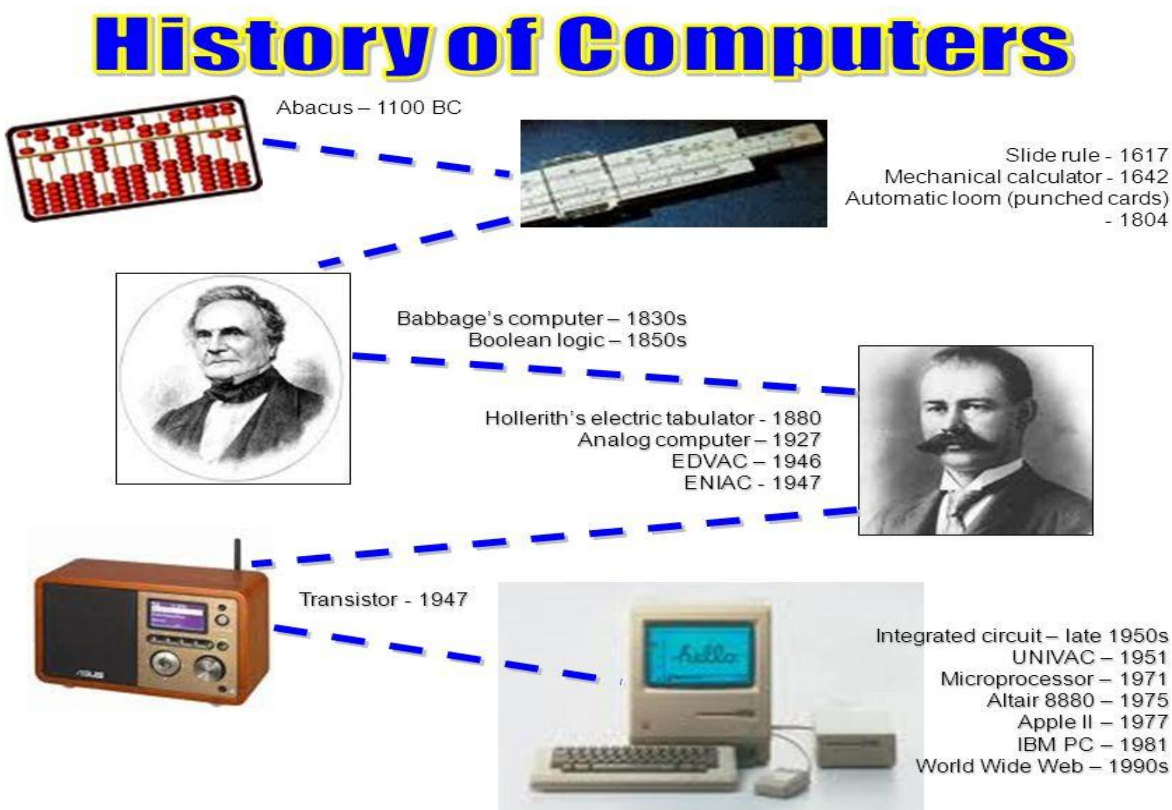
The hallmark of this period (1964-1971) was the development of the integrated circuit. A single integrated circuit (IC) is made up of many transistors, which increases the power of a computer while simultaneously lowering its cost. These computers were quicker, smaller, more reliable, and less expensive than their predecessors. High-level programming languages such as FORTRON-II to IV, COBOL, and PASCAL PL/1 were utilized. For example, the IBM360 series, the Honeywell-6000 series, and the IBM-370/168.

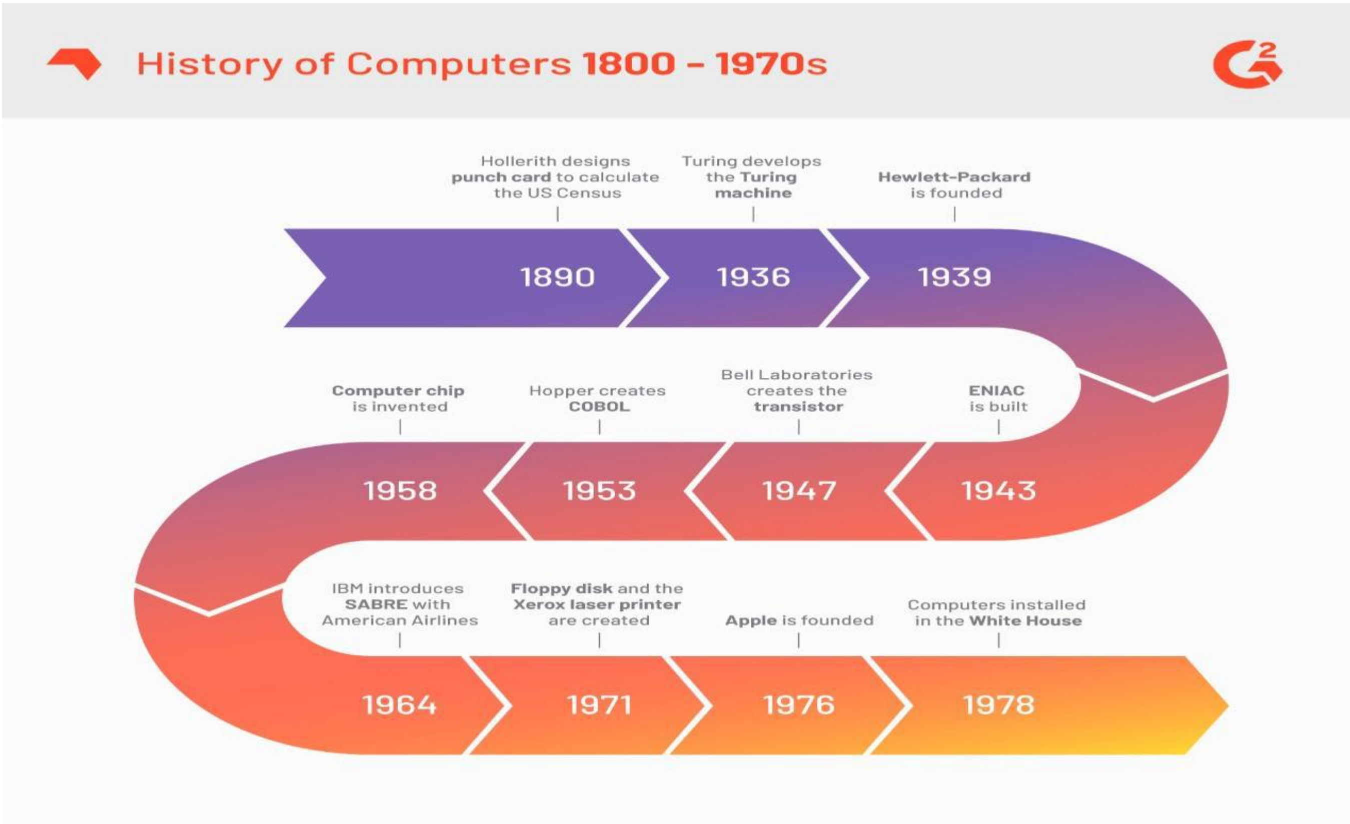
4 th Generation:-

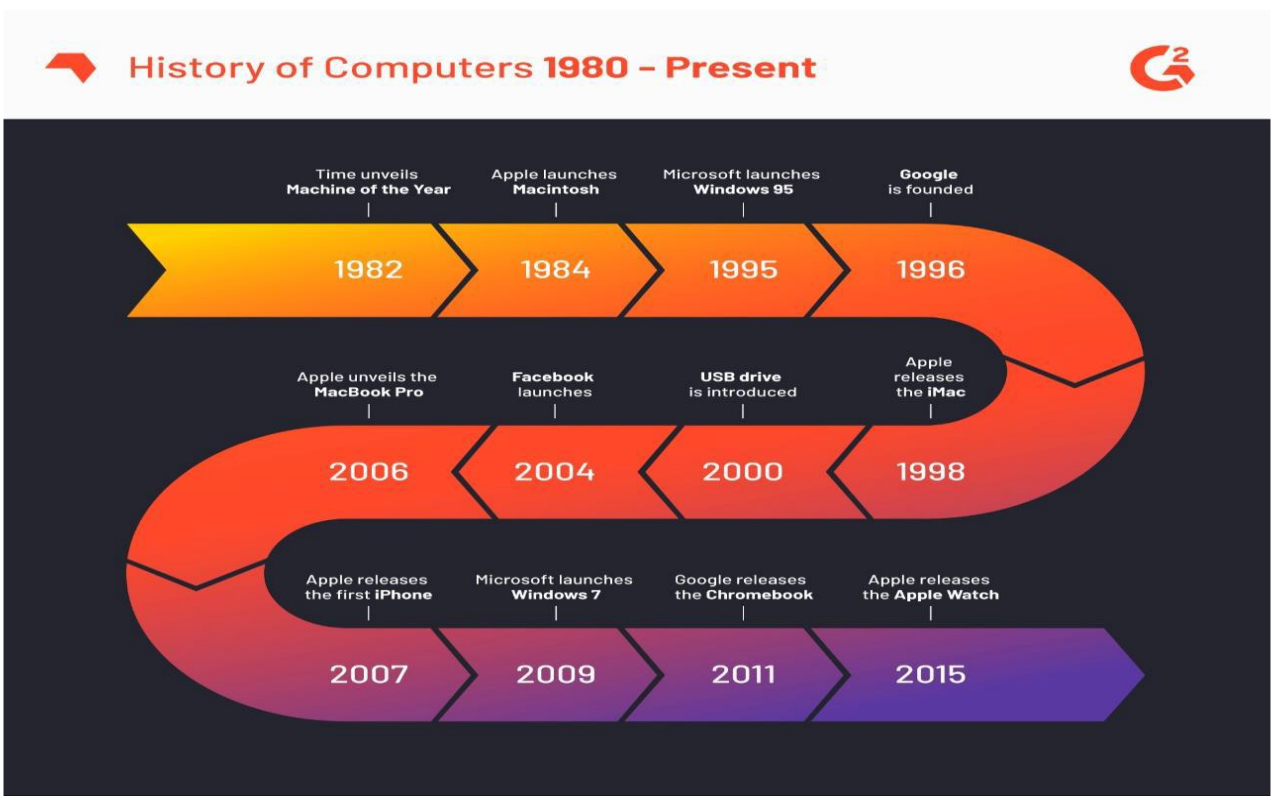
The invention of the microprocessors bought along the fourth generation of computers. The year 1971-1980 were dominated by fourth generation computers. C, C++ and Java was the programming language used in this generation of computers. For instance, the STAR 1000, PDP 11, CRAY-1MCRAY-X-MP AND Apple II. This was when we started producing computers for home use.

5 th Generation: -

These computers have been utilized since 1980 and continue to use it till now. This is the present and future of computer world. The defining aspect of this generation is artificial intelligence. The use of parallel processing and superconductors are making this a reality and providing a lot of scope for future. Fifth generation computers use ULSI (Ultra LargeScale Integration) technology. These are the most recent and sophisticated computers. C, C++, Java, Net and more programming language are used. For instance, IBM, Pentium, Desktop, Laptop, Notebook, Ultrabook and so on.




History of Computers 1800 – 1970s
Hollerith designs punch card to calculate the US Census
1890
Turing develops the Turing machine
1936
Hewlett-Packard is founded
1939
ENIAC is built
1943
Bell Laboratories creates the transistor
1947
Hopper creates COBOL
1953
Computer chip is invented
1958
IBM introduces SABRE with American Airlines
1964
Floppy disk and the Xerox laser printer are created
1971
Apple is founded
1976
Computers installed in the White House
1978


History of Computers 1980 – Present
Time unveils Machine of the Year
1982
Apple launches Macintosh
1984
Microsoft launches Windows 95
1995
Google is founded
1996
Apple releases the iMac
1998
USB drive is introduced
2000
Facebook launches
2004
Apple unveils the MacBook Pro
2006
Apple releases the first iPhone
2007
Microsoft launches Windows 7
2009
Google releases the Chromebook
2011
Apple releases the Apple Watch
2015

Types of computers:

Analog Computers:-

Analog computers are built with various components such as gears and livers with no electrical components. One advantage of analogue computation is that designing and building an analogue computer to tackle a specific problem can be quite straightforward.

Digital Computers: -

Information in digital computers is represented in discrete form, typically as sequence of 0's and 1's (binary digits or bits). A digital computer is a system or gadget that can process any type of information in a matter of seconds. Digital computers are categorized into many different types.

They are as follows:

1. Mainframe computers:-

It is a computer that is generally utilized by large enterprises for mission-critical activities such as massive data processing. Mainframe computers were distinguished by massive storage capacities, quick components, and powerful computational capabilities. Because they were complicated systems, they were managed by a team of systems programmers who had sole access to the computer. These machines are now referred to as servers rather than mainframes.

2. Supercomputers:-

The most powerful computers to date are commonly referred to as supercomputers. Supercomputers are enormous systems that are purpose-built to solve complicated scientific and industrial problems. Quantum mechanics, weather forecasting, oil and gas exploration, molecular modelling, physical simulations, aerodynamics, nuclear fusion research, and cryptoanalysis are all done on supercomputers.

3. Minicomputers:-

A minicomputer is a type of computer that has many of the same features and capabilities as a larger computer but is smaller in size. Minicomputers, which were relatively small and affordable, were often employed in a single department of an organization and were often dedicated to a specific task or shared by a small group.

4. Microcomputers:-

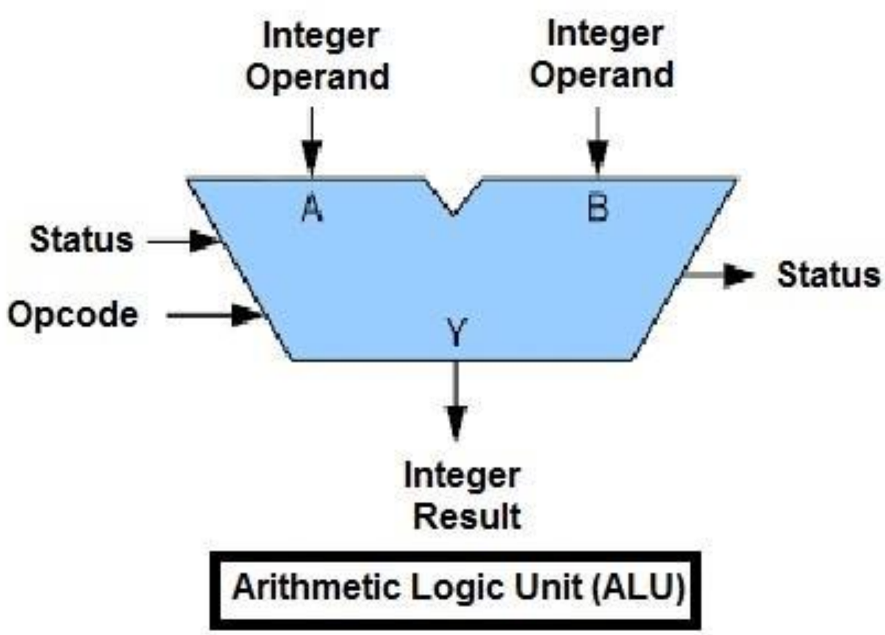
A microcomputer is a small computer that is based on a microprocessor integrated circuit, often known as a chip. A microcomputer is a system that incorporates at a minimum a microprocessor, program memory, data memory, and input-output system (I/O). A microcomputer is now commonly referred to as a personal computer (PC).

5. Embedded Processors:-

These are miniature computers that control electrical and mechanical processes with basic microprocessors. Embedded processors are often simple in design, have limited processing capability and I/O capabilities, and need little power. Ordinary microprocessors and microcontrollers are the two primary types of embedded processors. Embedded processors are employed in systems that do not require the computing capability of traditional devices such as desktop computers, laptop computers, or workstations.

Arithmetic Logical Unit (ALU):-

An arithmetic logic unit (ALU) is a major component of the central processing unit of the computer system. It does all the processes related to arithmetic and logical operations that needs to be done on instruction words. It is a capable of using logical operations. (e.g., AND, OR, Ex-OR etc.) in addition to arithmetic operation (Addition, Subtraction etc.). The control unit supplies the data required by the ALU from memory, or from input devices and directs the ALU to perform specific task based on the instruction fetched from the memory.



Different operation as carried out by ALU can be categorized as follows:

• **logical operations**: These include operations like AND, OR, NOT, XOR, NOR, NAND, etc.
• **Bit-Shifting Operations**: This pertains to shifting the positions of the bits by a certain number of places either towards the right or left, which is considered a multiplication or division operations.

• **Arithmetic operations**: This refers to bit addition and subtraction. Although multiplication and division are sometimes used, these operations are more expensive to make. Multiplication and subtraction can also be done by repetitive additions and subtractions respectively.

2. Write short notes on benchmark program?
In computing, a benchmark is the act of running a computer program, a set of programs, or other operation, in order to assess the relative performance of an object, normally by running a number of standard test and trial against it.
Benchmarking is usually associated with assessing performance characteristics of computer hardware, for example the floating-point operation performance of CPU, there are circumstances when the technique is also applicable to software. Software benchmarks are for example, run against compilers or database management system (DBMS). Benchmarks provide a method of comparing the performance of various subsystems across different chip/system architectures.

Purpose:
Benchmarks are particularly important in CPU design, giving processor architects the ability to measure and make tradeoffs in microarchitectural decisions. For example, if a benchmark extracts the key algorithms of an application, it will contain the performance-sensitive aspects of that application. Running this much smaller snippet on a cycle-accurate simulator can give clues on how to improve performance.

Benchmarking Principle:

There are seven vital characteristics for benchmarks. These key properties are:
1. Relevance: Benchmarks should measure relatively vital features.
2. Representativeness: Benchmark performance metrics should be broadly accepted by industry and academia.
3. Equity: All systems should be fairly compared.
4. Repeatability: Benchmark results can be verified.
5. Cost-effectiveness: Benchmark tests are economical.
6. Scalability: Benchmark tests should work across systems possessing a range of resources from low to high.
7. Transparency: Benchmark metrics should be easy to understand.

Parameters for Measing Performance:

• Wall-clock time (elapsed time). Latency to complete a task, including disk accesses, input/output activities, memory accesses, OS overhead
• CPU time. Not inclusion of time waiting for I/O or running another program.
• User CPU time. Time spent in the program
• System CPU time. Time spent in the OS

Types of Benchmark:

• **Real programs:**
They have input, output, and options that a user can select when running the program. Examples: Compilers, text processing software, etc.

• **Kernels. Small:**

Key pieces from real programs. They are not used for users. Examples: Livermore Loops and Linpack.

• **Toy benchmarks:**

Typically, between 10 and 100 lines of code and produce a result the user already knows. Examples: Sieve of Eratosthenes, Puzzle, and Quicksort.

• **Synthetic benchmarks:**
They try to match an average execution profile.
Examples: Whetstone and Dhrystone

• **Parallel benchmarks:**

Used on machines with multiple cores and/or processors, or systems consisting of multiple machines

• **Database benchmarks:**
Measure the throughput and response times of database management systems (DBMS)

Common benchmarks:

• Business Applications Performance Corporation (BAPCo)

• Embedded Microprocessor Benchmark Consortium (EEMBC)

• Linked Data Benchmark Council (LDBC)

• BAPCo: MobileMark, SYSmark, WebMark

• CrystalDiskMark

• Futuremark: 3DMark, PCMark

3. A benchmark program is run on a 40 MHz processor. The executed program consists of 100,000 instructions executions with the following instruction mix and clock cycle count

Instruction Type	Instruction Count	Cycles per Instruction
Integer Arithmetic	45,000	1
Data Transfer	32,000	2
Floating Point	15,000	2
Control Transfer	8000	2

Determine the effective CPI, MIPS rate and execution time for this program?

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③ - Formula for effective $CPI = \dfrac{\sum CPI * I_i}{I_c}$

Ⓐ. By given data,

$$\Rightarrow \frac{(45 \times 1 + 32 \times 2 + 15 \times 2 + 8 \times 2) \times 10^3}{(45+32+15+8) \times 10^3}$$

$$\Rightarrow \frac{155}{100} \Rightarrow (1.55 = CPI)$$

$CPI = 1.55$

Ⓑ Formula for MIPS rate

$$\text{MIPS rate} = \frac{\text{frequency}}{CPI}$$

$$\Rightarrow \frac{40 \times 10^6}{1.55 \times 10^6}$$

$$\Rightarrow 25.80$$

Ⓒ Execution time for program

$$\text{Execution time for program} = \frac{\text{Total inst}^n * CPI}{\text{frequency}}$$

$$\Rightarrow \frac{(45+32+15+8) \times 10^3 \times 1.55}{40 \times 10^6}$$

$$\Rightarrow 0.0038 \text{ Seconds}$$

(4) Consider three different processors P1, P2 and P3 executing the same instructions. P1 has 2.4 GHz and CPI of 1.5. P2 has 2.5GHz and CPI of 1.2. P3 has 3GHz and has a CPI of 2.3. Which processor has the highest performance expressed in instructions per second?

(4).

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$$P_1 = \frac{2.4 \text{ GHz}}{1.5}$$

$$\Rightarrow \frac{2.4}{1.5} \times 10^9$$

$\Rightarrow 1.6 \times 10^9$ insth/cycle second

$$P_2 = \frac{2.5 \text{ GHz}}{1.2}$$

$$= \frac{2.5 \times 10^9}{1.2}$$

$\Rightarrow 2.083 \times 10^9$ insth/second

$$P_3 = \frac{3 \text{ GHz}}{2.3}$$

$\Rightarrow 1.304 \times 10^9$ insth/second

So, P_2 has the highest performance among those.

(5) Assume for arithmetic, load and store and branch instructions, a CPU has CPI's of 1, 12 and 5 respectively. Also assume that on a single processor a program requires the execution of 2.56E9 arithmetic instructions, 1.28E9 load and store instructions and 256 million branch instructions. Assume that each processor has 2GHz of clock frequency. Assume that as the program is parallelized to run over multiple cores, the number of arithmetic and load and store instructions per processor is divided by 0.7 x p (where p is the number of processors) but the number of branch instructions per

processor remains the same. Find the total execution time for this program on 1, 2, 4 and 8 processors and find the speedup and efficiency?

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(5) Total Execution time

for No. of processors = 1

$$\Rightarrow \frac{(1 \times 2.56 \times 10^9) + (12 \times 128 \times 10^9) + (5 \times 2.56 \times 10^8)}{2 \times 10^9\ Hz}$$

$\Rightarrow$ 9.6 Sec

No of Processors = P = 2

$$\Rightarrow \frac{(1 \times 2.56 \times 10^9) + (12 \times 1.28 \times 10^9)}{0.7 \times 2} + \frac{(5 \times 2.56 \times 10^8)}{2 \times 10^9}$$

$\Rightarrow$ 7.04 Sec

No. of processor = P = 4

$$\Rightarrow \frac{(1 \times 2.56 \times 10^9) + (12 \times 1.28 \times 10^9)}{0.7 \times 4} + \frac{(5 \times 2.56 \times 10^8)}{2 \times 10^9}$$

$\Rightarrow$ 6.4 + 0.10

$\Rightarrow$ 6.5 Sec

No of processors = P = 8

$$\Rightarrow \frac{(1 \times 2.56 \times 10^9) + (12 \times 1.28 \times 10^9)}{0.7 \times 8} + \frac{(5 \times 2.56 \times 10^8)}{2 \times 10^9}$$

$\Rightarrow$ 3.2 + 0.64

$\Rightarrow$ 3.84 Sec

$$\text{speedup} = \frac{\text{Total Execution time (Single core)}}{\text{Total Execution time (multiple core)}}$$

for P = 2

$$\Rightarrow \frac{9.6\ Sec}{7.04\ Sec}$$

$\Rightarrow$ 1.36