Process management: Process concepts, Process states and Process Control Block, Context Switching, CPU Scheduler, Time quantum, CPU Bound, I/O bound.

Process concepts

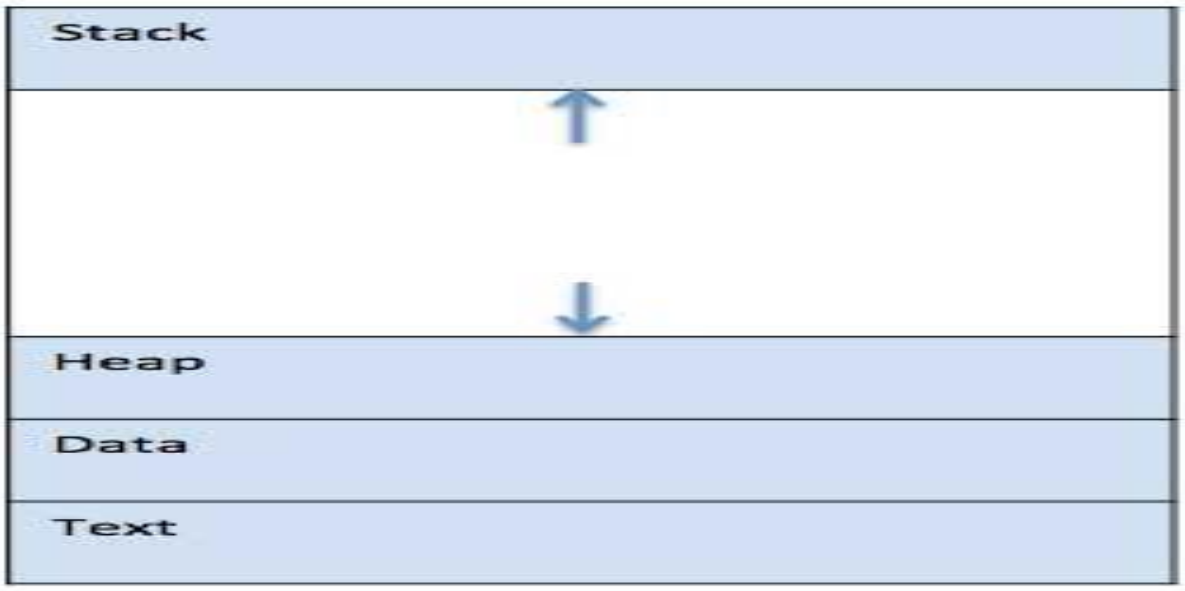
Process

A process is basically a program in execution. The execution of a process must progress in a sequential fashion.

A process is defined as an entity which represents the basic unit of work to be implemented in the system.

To put it in simple terms, we write our computer programs in a text file and when we execute this program, it becomes a process which performs all the tasks mentioned in the program.

When a program is loaded into the memory and it becomes a process, it can be divided into four sections ─ stack, heap, text and data. The following image shows a simplified layout of a process inside main memory –



S.N.	Component & Description
1	**Stack** The process Stack contains the temporary data such as method/function parameters, return address and local variables.
2	**Heap** This is dynamically allocated memory to a process during its run time.
3	**Text** This includes the current activity represented by the value of Program Counter and the contents of the processor's registers.

4	**Data** This section contains the global and static variables.

Program

A program is a piece of code which may be a single line or millions of lines. A computer program is usually written by a computer programmer in a programming language. For example, here is a simple program written in C programming language −

```
#include <stdio.h>

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

A computer program is a collection of instructions that performs a specific task when executed by a computer. When we compare a program with a process, we can conclude that a process is a dynamic instance of a computer program.

A part of a computer program that performs a well-defined task is known as an **algorithm**. A collection of computer programs, libraries and related data are referred to as a **software**.

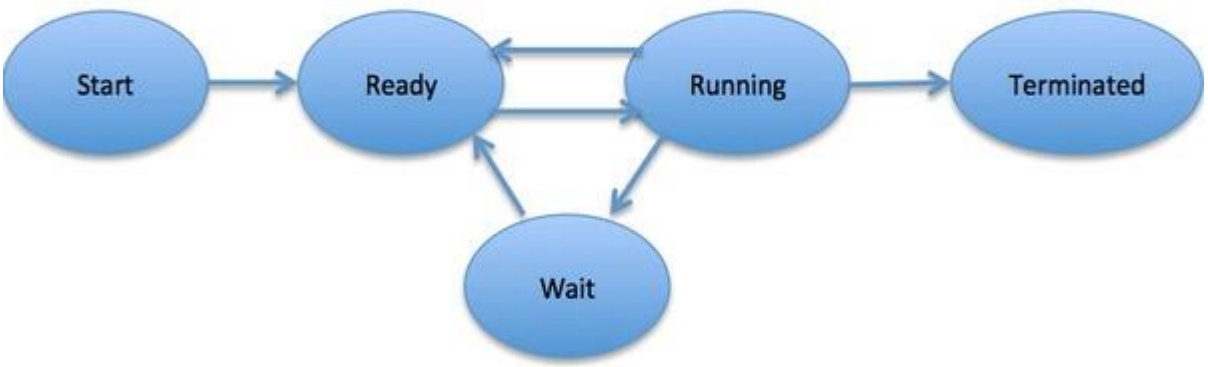
Process Life Cycle

When a process executes, it passes through different states. These stages may differ in different operating systems, and the names of these states are also not standardized.

In general, a process can have one of the following five states at a time.

S.N.	State & Description
1	**Start** This is the initial state when a process is first started/created.
2	**Ready** The process is waiting to be assigned to a processor. Ready processes are waiting to have the processor allocated to them by the operating system so that they can run. Process may come into this state after **Start** state or while running it by but interrupted by the scheduler to assign CPU to some other process.
3	**Running** Once the process has been assigned to a processor by the OS scheduler, the process state is set to running and the processor executes its instructions.

4	**Waiting** Process moves into the waiting state if it needs to wait for a resource, such as waiting for user input, or waiting for a file to become available.
5	**Terminated or Exit** Once the process finishes its execution, or it is terminated by the operating system, it is moved to the terminated state where it waits to be removed from main memory.



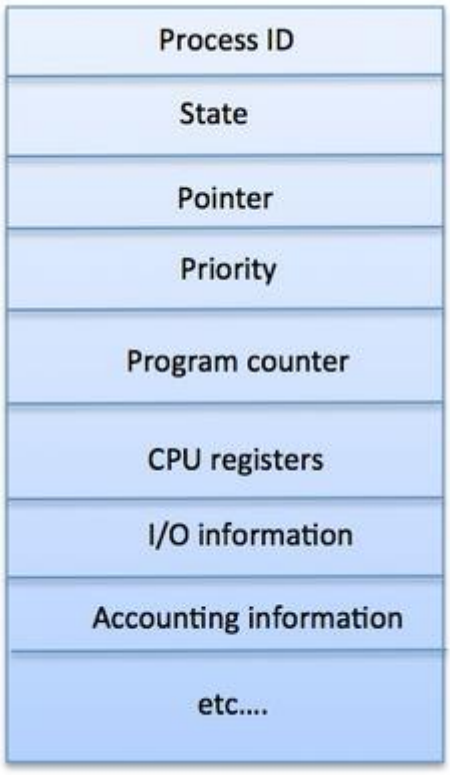
Process Control Block (PCB)

A Process Control Block is a data structure maintained by the Operating System for every process. The PCB is identified by an integer process ID (PID). A PCB keeps all the information needed to keep track of a process as listed below in the table –

S.N.	Information & Description
1	**Process State** The current state of the process i.e., whether it is ready, running, waiting, or whatever.
2	**Process privileges** This is required to allow/disallow access to system resources.
3	**Process ID** Unique identification for each of the process in the operating system.
4	**Pointer** A pointer to parent process.
5	**Program Counter** Program Counter is a pointer to the address of the next instruction to be executed for this process.
6	**CPU registers**

	Various CPU registers where process need to be stored for execution for running state.
7	**CPU Scheduling Information** Process priority and other scheduling information which is required to schedule the process.
8	**Memory management information** This includes the information of page table, memory limits, Segment table depending on memory used by the operating system.
9	**Accounting information** This includes the amount of CPU used for process execution, time limits, execution ID etc.
10	**IO status information** This includes a list of I/O devices allocated to the process.

The architecture of a PCB is completely dependent on Operating System and may contain different information in different operating systems. Here is a simplified diagram of a PCB –



The PCB is maintained for a process throughout its lifetime, and is deleted once the process terminates.

what are process states?

A **process** is a **program** in execution and it is more than a program code called as text section and this concept works under all the operating system because all the task perform by the **operating system** needs a process to perform the task

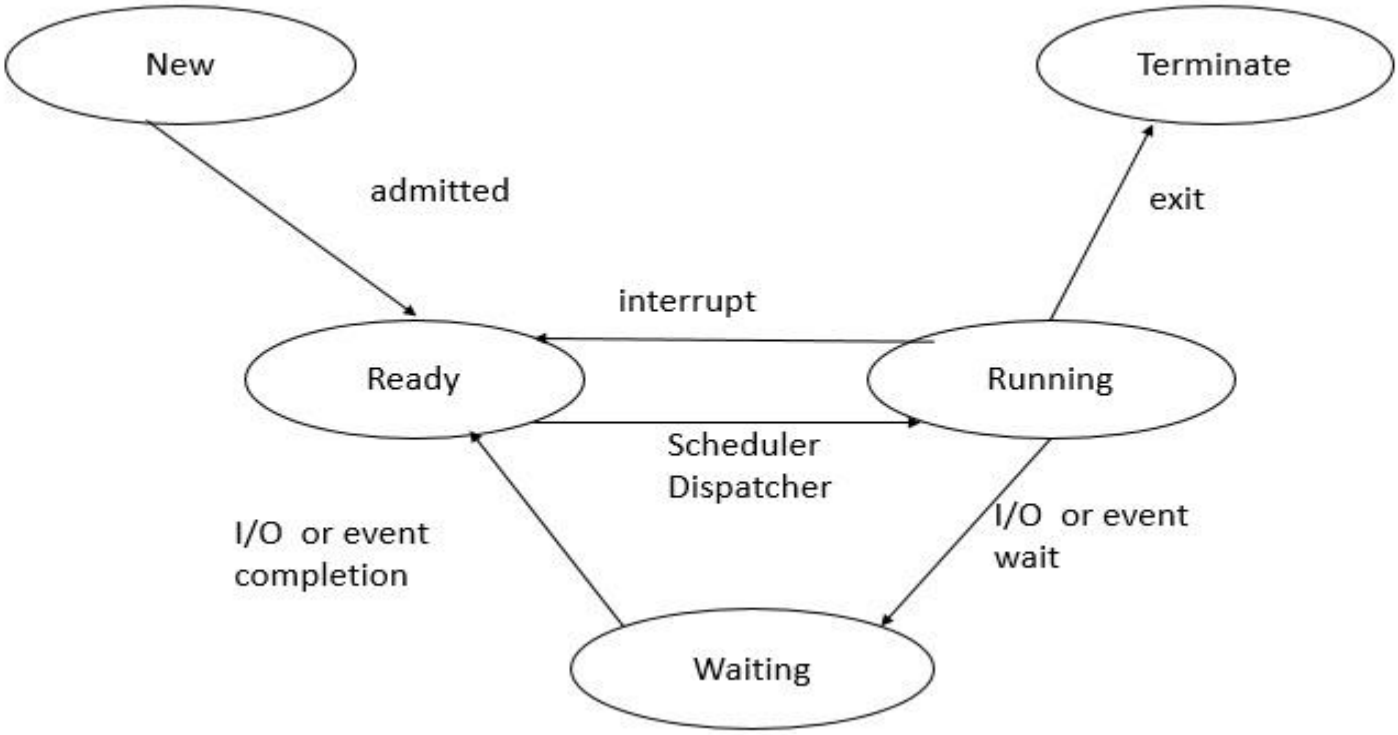
The process executes when it changes the state. The state of a process is defined by the current activity of the process.

Each process may be in any one of the following states –

- **New** – The process is being created.
- **Running** – In this state the instructions are being executed.
- **Waiting** – The process is in waiting state until an event occurs like I/O operation completion or receiving a signal.
- **Ready** – The process is waiting to be assigned to a processor.
- **Terminated** – the process has finished execution.

It is important to know that only one process can be running on any processor at any instant. Many processes may be ready and waiting.

Now let us see the state diagram of these process states –



Explanation

Step 1 – Whenever a new process is created, it is admitted into ready state.

Step 2 – If no other process is present at running state, it is dispatched to running based on scheduler dispatcher.

Step 3 – If any higher priority process is ready, the uncompleted process will be sent to the waiting state from the running state.

Step 4 – Whenever I/O or event is completed the process will send back to ready state based on the **interrupt signal** given by the running state.

Step 5 – Whenever the execution of a process is completed in running state, it will exit to terminate state, which is the completion of process.

Process Control Block

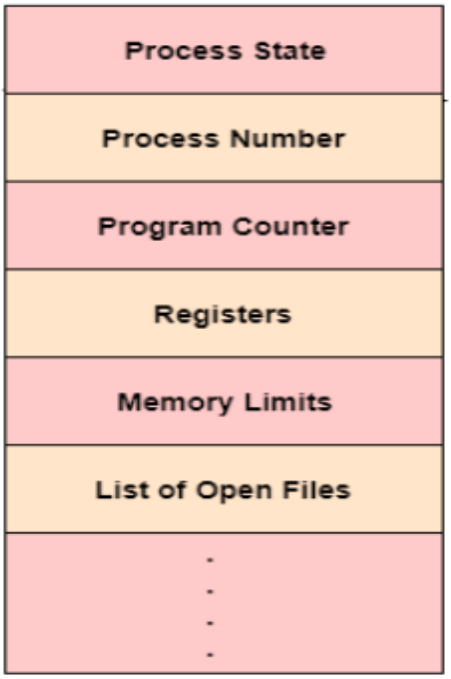
What is Process Control Block (PCB)?
Computer EngineeringMCAOperating System

Process Control Block is a **data structure** that contains information of the process related to it. The process control block is also known as a task control block, entry of the process table, etc.

It is very important for **process management** as the data structuring for processes is done in terms of the PCB. It also defines the current state of the **operating system**.

Structure of the Process Control Block

The process control stores many data items that are needed for efficient process management. Some of these data items are explained with the help of the given diagram –



Process Control Block (PCB)

The following are the data items –

Process State

This specifies the process state i.e. new, ready, running, waiting or terminated.

Process Number

This shows the number of the particular process.

Program Counter

This contains the address of the next instruction that needs to be executed in the process.

Registers

This specifies the registers that are used by the process. They may include **accumulators**, index registers, stack pointers, **general purpose registers** etc.

List of Open Files

These are the different files that are associated with the process

CPU Scheduling Information

The process priority, pointers to scheduling queues etc. is the **CPU scheduling** information that is contained in the PCB. This may also include any other scheduling parameters.

Memory Management Information

The memory management information includes the page tables or the segment tables depending on the memory system used. It also contains the value of the base registers, limit registers etc.

I/O Status Information

This information includes the list of **I/O devices** used by the process, the list of files etc.

Accounting information

The time limits, account numbers, amount of **CPU** used, process numbers etc. are all a part of the PCB accounting information.

Location of the Process Control Block

The process control block is kept in a memory area that is protected from the normal user access. This is done because it contains important process information. Some of the operating systems place the PCB at the beginning of the kernel stack for the process as it is a safe location.

What is Context Switching in Operating System?

Context Switching involves storing the context or state of a process so that it can be reloaded when required and execution can be resumed from the same point as earlier. This is a feature of a multitasking operating system and allows a single **CPU** to be shared by multiple processes.

A diagram that demonstrates context switching is as follows –

In the above diagram, initially Process 1 is running. Process 1 is switched out and Process 2 is switched in because of an interrupt or a system call. Context switching involves saving the state of Process 1 into PCB1 and loading the state of process 2 from PCB2. After some time again a context switch occurs and Process 2 is switched out and Process 1 is switched in again. This involves saving the state of Process 2 into PCB2 and loading the state of process 1 from PCB1.

Context Switching Triggers

There are three major triggers for context switching. These are given as follows –

- **Multitasking:** In a multitasking environment, a process is switched out of the CPU so another process can be run. The state of the old process is saved and the state of the new process is loaded. On a pre-emptive system, processes may be switched out by the scheduler.
- **Interrupt Handling:** The hardware switches a part of the context when an interrupt occurs. This happens automatically. Only some of the context is changed to minimize the time required to handle the interrupt.
- **User and Kernel Mode Switching:** A context switch may take place when a transition between the user mode and kernel mode is required in the operating system.

Context Switching Steps

The steps involved in context switching are as follows –

- Save the context of the process that is currently running on the CPU. Update the process control block and other important fields.
- Move the process control block of the above process into the relevant queue such as the ready queue, I/O queue etc.
- Select a new process for execution.
- Update the process control block of the selected process. This includes updating the process state to running.
- Update the memory management data structures as required.
- Restore the context of the process that was previously running when it is loaded again on the processor. This is done by loading the previous values of the process control block and registers.

Context Switching Cost

Context Switching leads to an overhead cost because of TLB flushes, sharing the cache between multiple tasks, running the task scheduler etc. Context switching between two threads of the same process is faster than between two different processes as threads have the same virtual memory maps. Because of this TLB flushing is not required.

CPU Scheduler:

Short Term Scheduler

It is also called as **CPU scheduler**. Its main objective is to increase system performance in accordance with the chosen set of criteria. It is the change of ready state to running

state of the process. CPU scheduler selects a process among the processes that are ready to execute and allocates CPU to one of them.

Short-term schedulers, also known as dispatchers, make the decision of which process to execute next. Short-term schedulers are faster than long-term schedulers.

Time quantum:

In operating systems, **time quantum** refers to the following:

- It is the amount of time spent on each process in the CPU until a context switch to the next process in the ready queue[1].
- CPU is assigned to the process on the basis of FCFS for a fixed amount of time, which is called the time quantum or time slice. After the time quantum expires, the running process is pre-empted and sent to the ready queue[2].

What Does CPU-Bound Mean?

The term CPU-bound describes a scenario where the execution of a task or program is highly dependent on the CPU. Before we go any further, let's define what a CPU is. The CPU usually refers to the central processing unit of a computing device, such as a desktop computer. It's responsible for controlling the execution of tasks and programs in a computer system. As such, a computing device can't really function without it.

In a CPU-bound environment, most times, the processor is the only component being used for execution. This means that other components in the computer system are rarely used during execution. Due to this dependence, everything concerned with program execution is dependent on the CPU. Consequently, if we want a program to run faster, then we have to increase the speed of the CPU.

Furthermore, CPU-bound operations tend to have few and long CPU bursts. CPU burst refers to the amount of time taken to execute a task, usually with the CPU. As a result, it's always advisable to assign a lower priority to such tasks to prevent wasting resources:

Process Scheduling

Previous

Next

Definition

The process scheduling is the activity of the process manager that handles the removal of the running process from the CPU and the selection of another process on the basis of a particular strategy.

Process scheduling is an essential part of a Multiprogramming operating systems. Such operating systems allow more than one process to be loaded into the executable memory at a time and the loaded process shares the CPU using time multiplexing.

Categories of Scheduling

There are two categories of scheduling:

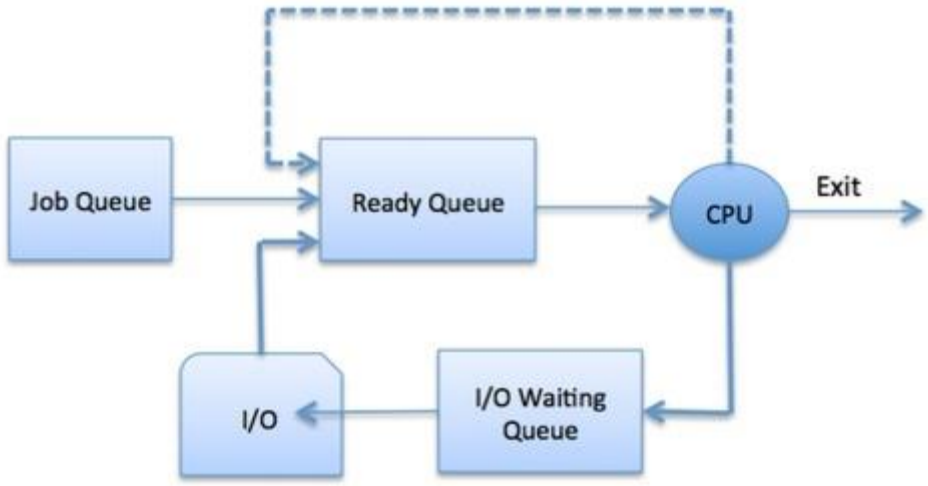
1. **Non-preemptive:** Here the resource can't be taken from a process until the process completes execution. The switching of resources occurs when the running process terminates and moves to a waiting state.
2. **Preemptive:** Here the OS allocates the resources to a process for a fixed amount of time. During resource allocation, the process switches from running state to ready state or from waiting state to ready state. This switching occurs as the CPU may give priority to other processes and replace the process with higher priority with the running process.

Process Scheduling Queues

The OS maintains all Process Control Blocks (PCBs) in Process Scheduling Queues. The OS maintains a separate queue for each of the process states and PCBs of all processes in the same execution state are placed in the same queue. When the state of a process is changed, its PCB is unlinked from its current queue and moved to its new state queue.

The Operating System maintains the following important process scheduling queues –

- **Job queue** – This queue keeps all the processes in the system.
- **Ready queue** – This queue keeps a set of all processes residing in main memory, ready and waiting to execute. A new process is always put in this queue.
- **Device queues** – The processes which are blocked due to unavailability of an I/O device constitute this queue.



The OS can use different policies to manage each queue (FIFO, Round Robin, Priority, etc.). The OS scheduler determines how to move processes between the ready and run

queues which can only have one entry per processor core on the system; in the above diagram, it has been merged with the CPU.

Two-State Process Model

Two-state process model refers to running and non-running states which are described below –

S.N.	State & Description
1	**Running** When a new process is created, it enters into the system as in the running state.
2	**Not Running** Processes that are not running are kept in queue, waiting for their turn to execute. Each entry in the queue is a pointer to a particular process. Queue is implemented by using linked list. Use of dispatcher is as follows. When a process is interrupted, that process is transferred in the waiting queue. If the process has completed or aborted, the process is discarded. In either case, the dispatcher then selects a process from the queue to execute.

Schedulers

Schedulers are special system software which handle process scheduling in various ways. Their main task is to select the jobs to be submitted into the system and to decide which process to run. Schedulers are of three types –

- Long-Term Scheduler
- Short-Term Scheduler
- Medium-Term Scheduler

Long Term Scheduler

It is also called a **job scheduler**. A long-term scheduler determines which programs are admitted to the system for processing. It selects processes from the queue and loads them into memory for execution. Process loads into the memory for CPU scheduling.

The primary objective of the job scheduler is to provide a balanced mix of jobs, such as I/O bound and processor bound. It also controls the degree of multiprogramming. If the degree of multiprogramming is stable, then the average rate of process creation must be equal to the average departure rate of processes leaving the system.

On some systems, the long-term scheduler may not be available or minimal. Time-sharing operating systems have no long term scheduler. When a process changes the state from new to ready, then there is use of long-term scheduler.

Short Term Scheduler

It is also called as **CPU scheduler**. Its main objective is to increase system performance in accordance with the chosen set of criteria. It is the change of ready state to running state of the process. CPU scheduler selects a process among the processes that are ready to execute and allocates CPU to one of them.

Short-term schedulers, also known as dispatchers, make the decision of which process to execute next. Short-term schedulers are faster than long-term schedulers.

Medium Term Scheduler

Medium-term scheduling is a part of **swapping**. It removes the processes from the memory. It reduces the degree of multiprogramming. The medium-term scheduler is in-charge of handling the swapped out-processes.

A running process may become suspended if it makes an I/O request. A suspended processes cannot make any progress towards completion. In this condition, to remove the process from memory and make space for other processes, the suspended process is moved to the secondary storage. This process is called **swapping**, and the process is said to be swapped out or rolled out. Swapping may be necessary to improve the process mix.

Comparison among Scheduler

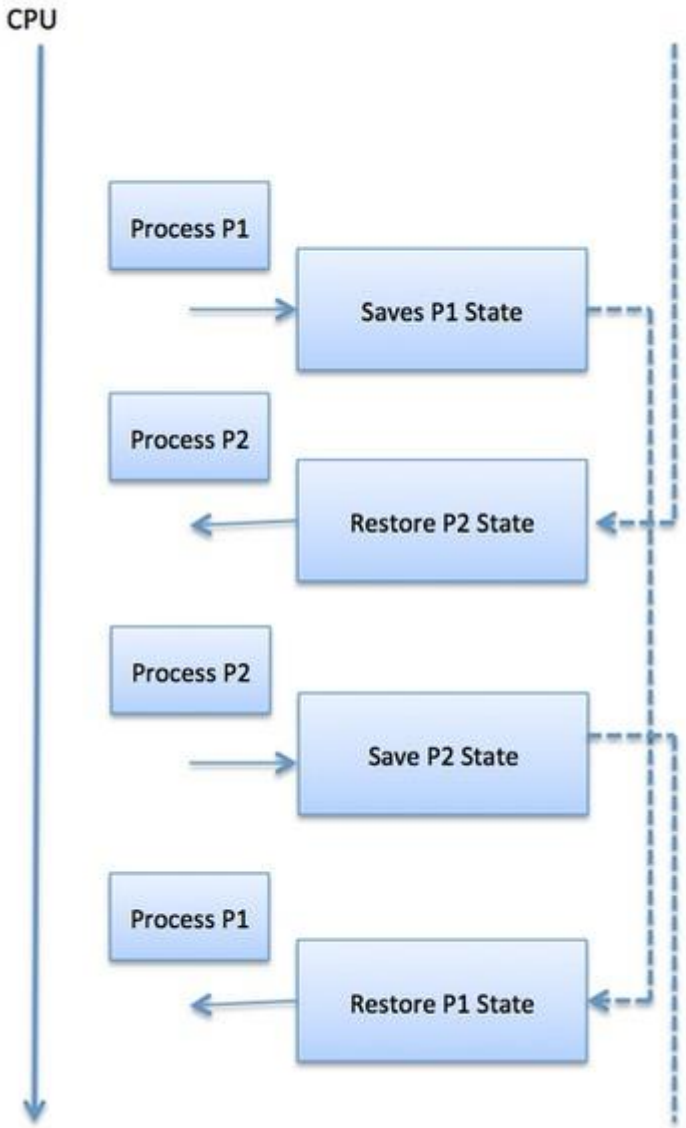
S.N.	**Long-Term Scheduler**	**Short-Term Scheduler**	**Medium-Term Scheduler**
1	It is a job scheduler	It is a CPU scheduler	It is a process swapping scheduler.
2	Speed is lesser than short term scheduler	Speed is fastest among other two	Speed is in between both short and long term scheduler.
3	It controls the degree of multiprogramming	It provides lesser control over degree of multiprogramming	It reduces the degree of multiprogramming.
4	It is almost absent or minimal in time sharing system	It is also minimal in time sharing system	It is a part of Time sharing systems.

5	It selects processes from pool and loads them into memory for execution	It selects those processes which are ready to execute	It can re-introduce the process into memory and execution can be continued.

Context Switching

A context switching is the mechanism to store and restore the state or context of a CPU in Process Control block so that a process execution can be resumed from the same point at a later time. Using this technique, a context switcher enables multiple processes to share a single CPU. Context switching is an essential part of a multitasking operating system features.

When the scheduler switches the CPU from executing one process to execute another, the state from the current running process is stored into the process control block. After this, the state for the process to run next is loaded from its own PCB and used to set the PC, registers, etc. At that point, the second process can start executing.



Context switches are computationally intensive since register and memory state must be saved and restored. To avoid the amount of context switching time, some hardware systems employ two or more sets of processor registers. When the process is switched, the following information is stored for later use.

- Program Counter
- Scheduling information
- Base and limit register value
- Currently used register
- Changed State
- I/O State information
- Accounting information