(8) Chapter (2)

Unit-2 (Ch-2)
Processes

CH-2 (25)

Process Management The CPU can execute only one instruction and that instruction can belong to only one ~~instruction~~ of the programs residing in the memory. Therefore, the OS have to allocate the CPU time to various users based on a certain policy. This is done by the Process Management (PM) module.

Process - Process is a program under execution. It is an active entity and a unit of work. It has a limited time span. Process consists of program code (text section), system stack (parameters, return addresses, local variables), data section (global variables) and process control block (PCB) (process state, program counter, PID, registers)

A program is a passive entity, such as the contents of a file stored on disk, whereas a process is an active entity with a program counter specifying the next instruction to execute and a set of associated resources

Process State

As a process ~~is~~ executes, it changes the state. The state of a process is defined by the current activity of that process. Each process may be in one of the following states:

- New: The process is being created.
- Running: Instructions are being executed
- Waiting: The process is waiting for some event to occur (such as an I/O completion or reception of signal)

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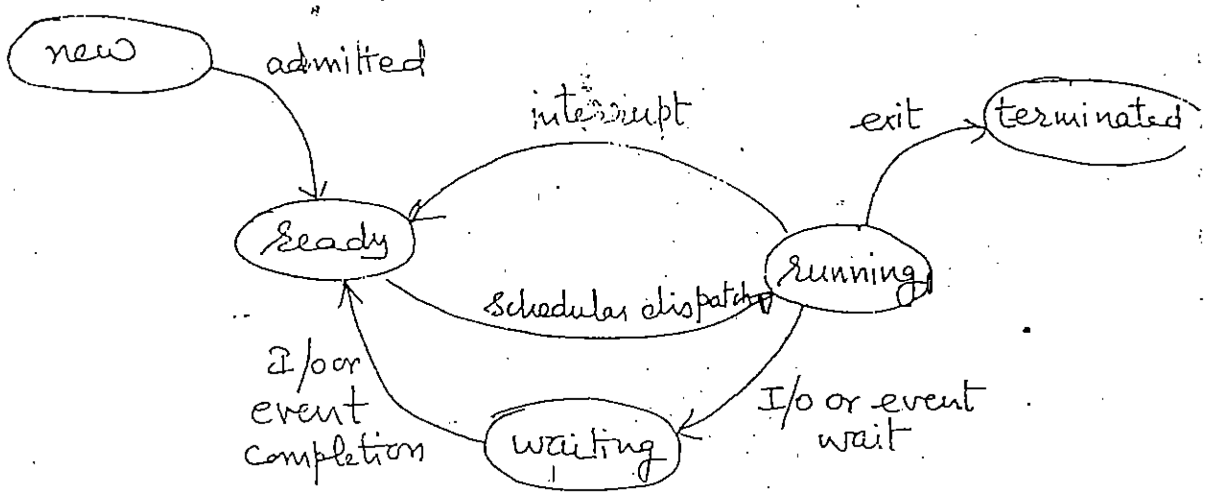
- Ready : The process is waiting to be assigned to processor.
- Terminated : The process has finished execution.



Different process states

There states may vary across operating systems. Only one process can be running on any processor at any instant, although many processes may be ready and waiting.

Process Control Block An OS considers a process to be the fundamental unit for resource allocation such as memory, swap space, IO Device, files owned by the process, CPU time etc.
Whenever a process is created, a process control block (PCB), is created for the process by OS. This is a data structure that is used by an OS to keep track of all information concerning a process. The PCB of a process contains the following information.

Pointer	Process State
Process Identification Number	
Program Counter	
registers	
memory limits	
list of open files	
⋮	

Process Control block (PCB)

Fields in a PCB :-

1) Pointer. It is a pointer to the next PCB in the process scheduling list.

2) Process State The state of process may be new, ready, running, waiting and so on.

3) Program Counter: The counter indicates the address of the next instruction to be executed for this process.

4, Process identification number: This is the unique number allocated by the OS to the process on creation.

5. Registers: The CPU registers include accumulators, index registers, stack pointers, and general purpose registers. Along with the program counter, this state information must be saved when an interrupt occurs, to allow the process to be continued correctly afterward.

6. Memory limits: Memory addresses in virtual memory.

7. List of open files: The files which ~~were~~ are being used by the process.

8. Other information may be:

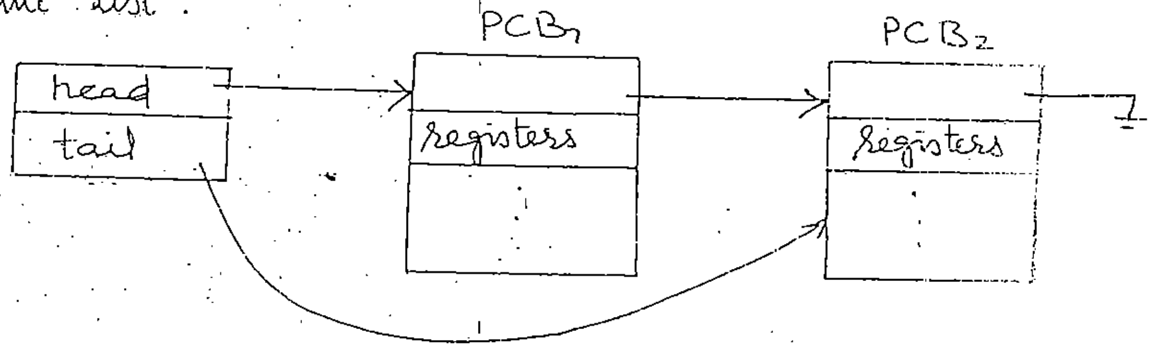
- CPU scheduling info: This information includes a process priority, pointers to scheduling queues, and any other scheduling parameters.
- Memory management info: This information includes the values of the base and limit registers, page table or ~~x~~ segment tables depending on the memory system used by the OS.
- Accounting info: This information includes the amount of CPU ~~used~~ time used, job or process numbers etc.
- I/O status info: It includes the list of I/O devices allocated to this process.

Process Scheduling:

P. Scheduling refers to a set of policies and mechanisms built into the OS that governs the ~~operat~~ order in which processes should be submitted to the CPU for execution.

Scheduling Queues: As a process enters the system, it is put into a job queue. This queue consists of processes in the system.

Ready queue: The processes that are residing in main memory and are ready and waiting to execute are kept on a list called the ready queue. Queue is stored as a link list. Header contains pointers to the ~~first~~ ~~the~~ first and final PCBs in the list.



Ready Queue

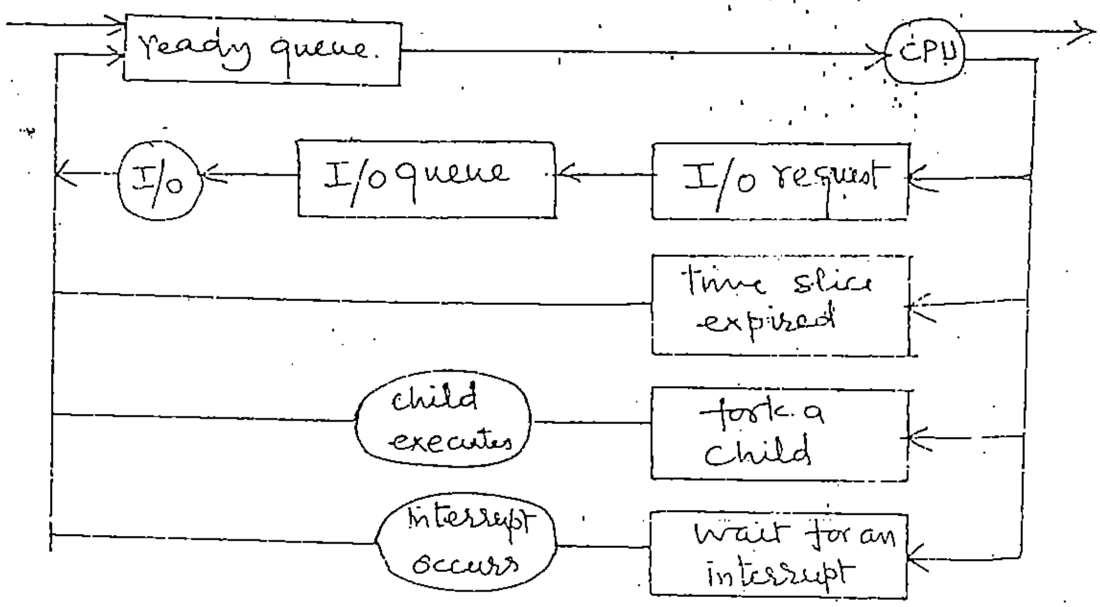
The operating system also has other queues such as
device queue - list of processes waiting for I/O device. Each device has its own device queue.

Process Scheduling can be represented by queueing diagram. Two types of queues are there: ready queue and ~~dev~~ device queue.

- A new process is initially put in ready queue. It waits in the ready queue until it is selected for execution. Once the process is assigned to the CPU and is executing, one of several events could occur:

- The process could issue an I/O request, and then be placed in an I/O queue.
- The process could create a new sub-process and wait for its termination.
- The process could be removed forcibly from the CPU, as a result of an interrupt, and be put back in the ready queue.

A process continues this cycle until it terminates, at ~~which time~~ that time it is removed from all queues and has its PCB and resources deallocated.



Process Scheduling - Queueing representation

Schedulers: The operating system must select the processes from different queues for execution at that time or over the time. This selection process is carried out by the appropriate scheduler.

Long term scheduler: The function of the long term scheduler is selects the jobs from the pool of jobs and loaded into main memory in ready queue. Thus, long term scheduler is also known as job scheduler.

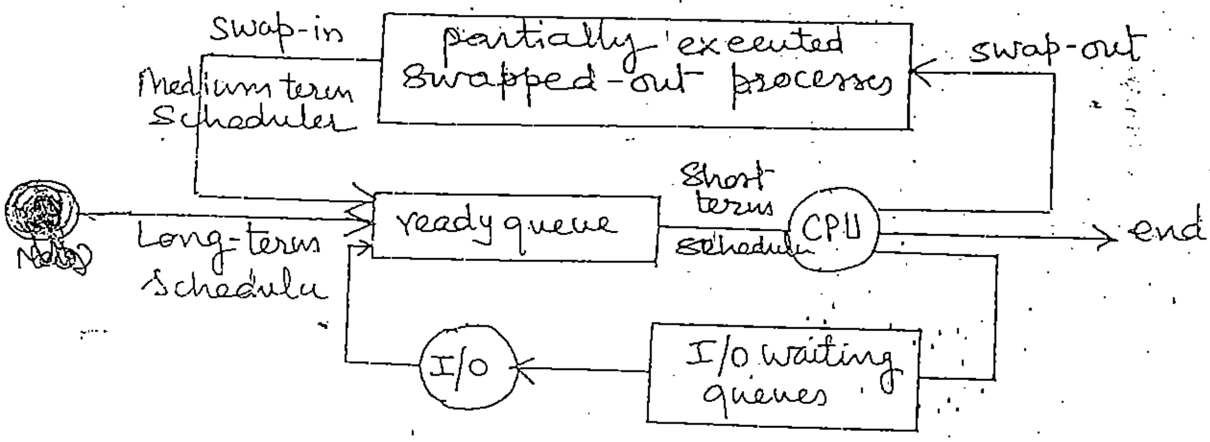
The long term scheduler must make a careful selection. Processes can be described either I/o bound or CPU bound. An I/o bound process spends more of its time doing I/o bound tasks and CPU bound processes generate I/o requests infrequently, using most of the time CPU. Long term Scheduler should select a good process mix of I/o & CPU bound processes. If all are I/o bound, the ready queue will always be empty. If all are CPU bound, I/o device queue will be empty and system will be imbalanced.

The long term scheduler executes much less frequently.

Short term Scheduler. It selects the process (from main memory) which among the processes which are ready to execute and allocates the CPU to that process. It is also known as CPU Scheduler. Short term Scheduler executes at least once every 100 milliseconds.

It is also called as dispatcher

Medium term Scheduler : Some OS, such as time sharing systems may introduce an additional intermediate level of scheduling. It removes processes from memory. At some later time the process can be reintroduced into memory and its execution can be continued where it left off. This process is called swapping which is necessary to improve the process mix and to free up some main memory.

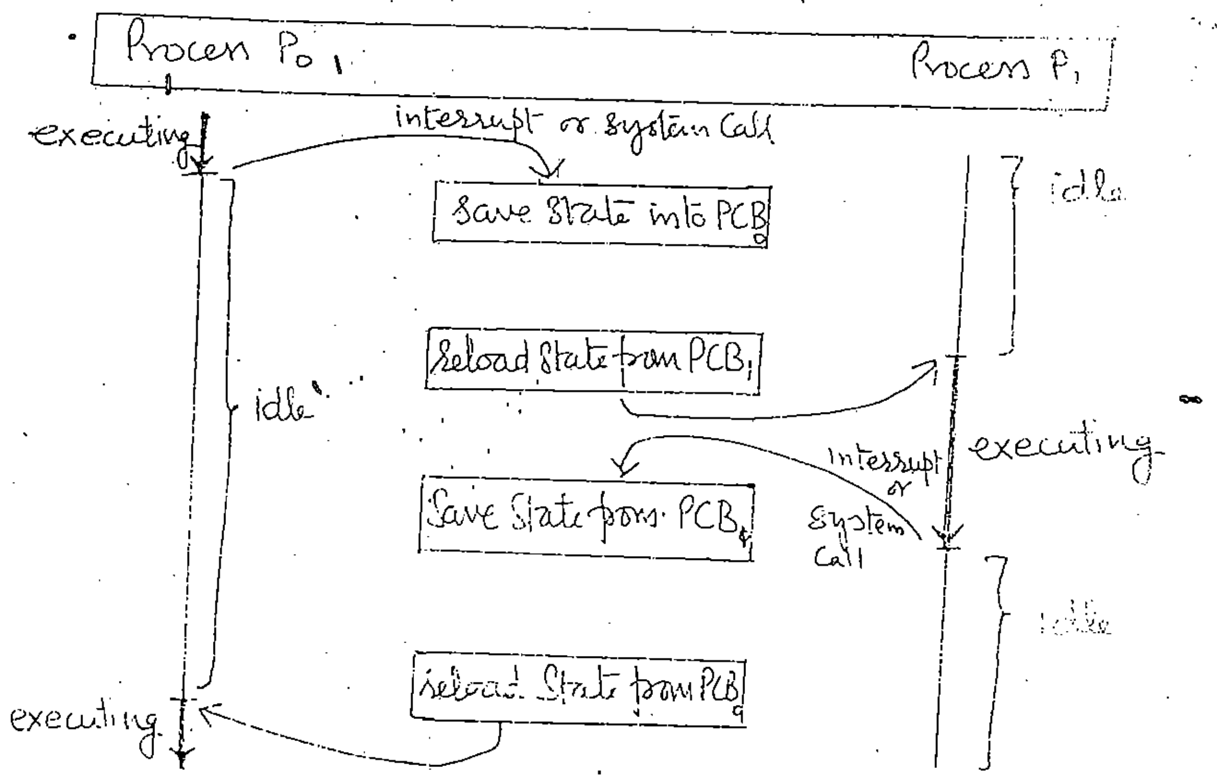


Different types of Schedulers and their actions.

Diff b/w Blocking & unblocking com/.

Context Switch: Switching the CPU from one process to another process requires saving the state of the old process and loading the saved state for the new process. This task is known as context switch. The context of a process is represented in the PCB of a process; it includes the value of the CPU registers, the process state and memory management ~~function~~ information. Context switch time is pure overhead, because system does not perform any useful work (or CPU work) while switching.

The switching speed varies from machine to machine, depending on the memory speed, the no. of registers that must be copied etc.



CPU Switch from process to process

~~Cooperating processes~~ (Co-operating Processes) heading is Test

Concurrent processes (reading: Concurrent Processes)

Concurrent processes In a single-processor multiprogramming system, processes are interleaved in time to yield the appearance of simultaneous executi[on]. Even though actual parallel processing is not achieved interleaved execution provides major benefits in processing efficiency. In a multiple processor syste[m] it is possible not only to interleave processes bu[t] also to overlap them.

Thus, two processes are known as concurr[ent] processes, if their execution can interleave or overlap in time.

The concurrent processes may be either indepe-dent processes or cooperating processes.

Independent processes :- The processes which ar[e] not affected by each other and they do not share any data, are called independent process[es].

Cooperating processes :- The processes which a[re] affected by each other or they share any data, are called cooperating processes.

Processes cooperation is needed due to following reasons

(i) Informationsharing : Many processes need to sha[re] the piece of information such as files, data etc, we must provide an environment to allow concurrent access to these data type of resource

(ii) Computation speed up : A ~~proce~~ task should be broken into smaller subtasks for faster execution, each will be executing in parallel with each other. These subtasks are cooperating processes because affect each other.

(iii) Modularity : System may be developed in modular structure to give high extensibility & flexibili[ty].

(iv) Convenience : An individual user may have many tasks parallel such as: printing, editing etc.

where each thread may be running in parallel on a different processor. In a single processor architecture, the CPU generally moves between each thread so quickly as to create the illusion of parallelism, but in reality only one thread is running at a time.

User and Kernel threads: Support for threads may be provided at either the user level, for user threads or by the kernel, for kernel threads.

1) User threads:

- These are supported above the kernel and are implemented by a thread library at user level
- Library provides thread creation, scheduling, management with no support from kernel.
- No kernel intervention is required
- User level threads are fast to create and manage. • user thread libraries include Posix thread, Solaris 2 - UI Thread.

Drawback: If kernel is single-threaded, then any user-level thread gets blocked due to some system call. This causes the entire process to block even if other ~~process~~ threads are available to run.

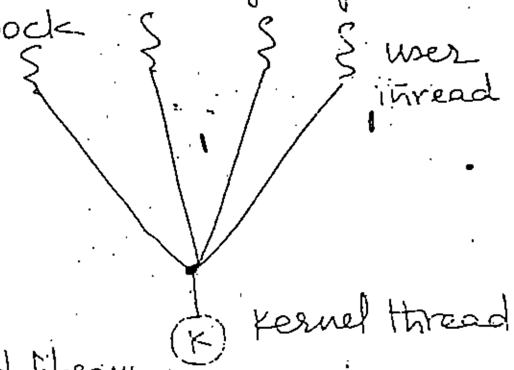
2) Kernel threads. Kernels threads are supported by OS

- Kernel performs thread creation, scheduling, management in kernel space.
- Kernel threads are slower than user threads (to create and manage)
- If a ~~user~~ thread performs a blocking system call the kernel can schedule another kernel thread
- In multiprocessor environment, the kernel can schedule threads on different processors. e.g. Windows NT, Windows 2000, Solaris 2, BeOS, Tru 64 UNIX.

Multithreading Models: Many systems provide support for both user and kernel threads, resulting in different multithreading models.

Many-to-one Model:

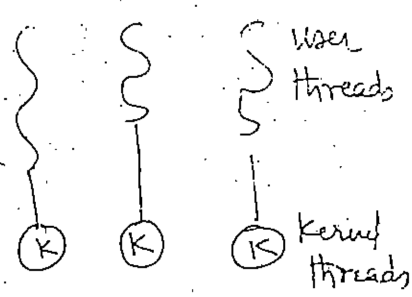
- It maps many user-level threads to one kernel thread.
- Thread management is carried out in user space so it is efficient.
- But, if one thread makes a blocking system call then entire process will block.
- Only one user thread can access the kernel at a time, multiple threads are unable to run in parallel on multiprocessors.



e.g Green threads - a thread library in solaris 2

One-to-one Model:

- It maps each user thread to a kernel thread.
- It allows another thread to run when a thread makes a blocking system call which provides more concurrency.
- It also allows multiple thread to run in parallel on multiprocessors.
- But Creating a user thread requires creating the corresponding kernel thread. This overheads can reduce the application performance.



e.g - Windows NT, Windows 2000, and OS/2

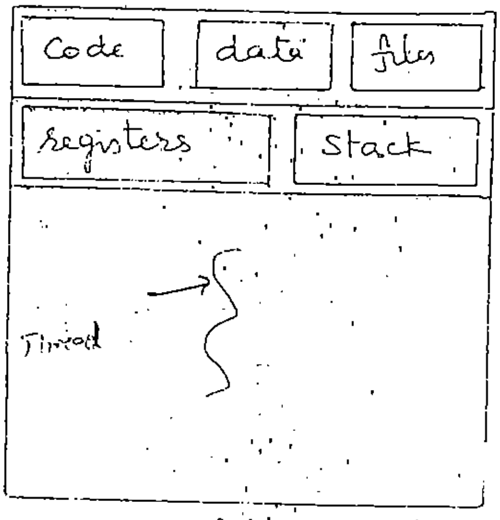
Unit 2 (Ch-5)

Threads

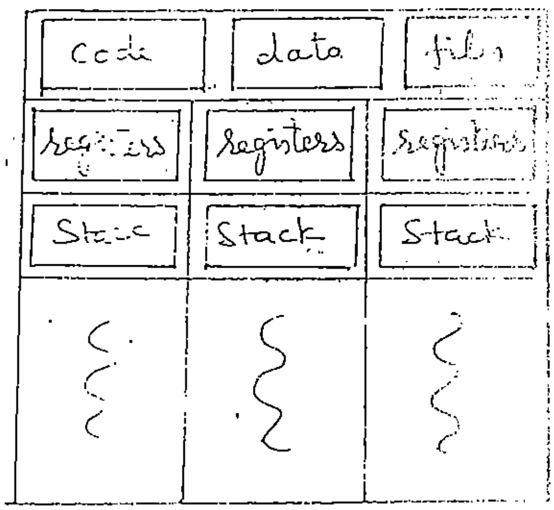
Multithreading refers to the ability of an OS to support multiple threads of execution within a single process.

A thread:

- referred as a light-weight process (LWP)
- a basic unit of CPU utilization
- it has a thread ID, a program counter, a register set and a stack.
- it shares code section, data section, open files etc. with other threads belonging to the same process
- threads are tightly coupled
- a single process control block and uses address space associated with the process and all threads belonging this process.
- Each thread has its own thread control block having Id, counter, register set and other related info



Single-threaded



Multi-threaded

e.g. Web browser — (i) Displaying message or text or image
(ii) retrieves data from network

Word processor — (i) Displaying graphics
(ii) Reading key strokes
(iii) Spelling & grammar checking

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If an application should be implemented as a set of related units of execution. There are two ways:

1) Multiple processes – which are heavy weight and less efficient.

2, Multiple threads – Multiple threads are more useful because of following characteristics:

- Multiple threads are light weight because of share memory.
- Thread creation and termination processes are less time consuming
- Context switch between two threads takes less time.
- Communication between threads is fast because threads share address space, intervention of kernel is not required.

Benefits: Benefits of multithreaded progs can be broken down into 4 categories.

(1) Responsiveness: A process continues running even if one thread is blocked or performing lengthy operation which increases the responsiveness to the user.

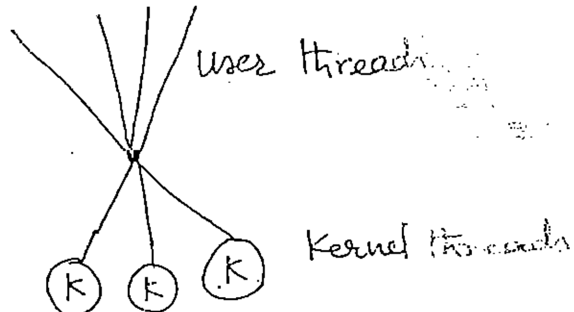
(2) Resource Sharing: Threads share memory and resources of the process to which they belong. It allows an application to have several different threads of activity all within the same address space.

(3) Economy: Threads share memory and resources of the process to which they belong, it is more economical to create & context switch threads. Also, thread managing is less time consuming than process management. e.g. In Solaris 2, creating a ~~thread~~ process is 30 times slower than creating a thread. Context switch in process is 5 times slower than in threads.

(4) Utilization of Multiprocessor Architecture – Multithreading on a multiprocessor architecture increases the concurrency,

3. Many-to-many Model:

- It multiplexes many user-level threads to a smaller or equal no. of kernel threads.
- Numbers of kernel threads may be specific to either a particular application or a particular machine.



Concurrency in multithreading Model:

1. Many to one model does not provide true concurrency because kernel can schedule only one thread at a time.
2. One to one model provides greater concurrency but the developer has to be careful not to create ~~greate~~ too many threads within an application

Threading Issues

1. The fork and exec System Calls:

- fork() call either duplicates all threads or duplicates only the thread that invoked the fork().
- The exec() will replace the entire process including all threads and LWPs with the program which is specified in the parameter of exec().
- If fork() is followed by exec() immediately, it duplicates the process with the current thread
- If fork() is not followed by exec(), it duplicates the process with all threads.

2. Cancellation: Thread cancellation is the task of terminating a thread before it has completed. e.g. if multiple threads are concurrently searching through a database and one thread returns the result, the remaining threads might be cancelled.

The thread that is to be cancelled is referred to as the target thread.

Cancellation may occur in two different situations:

(i) Asynchronous Cancellation: One thread immediately terminates the target thread. e.g. most OS

(ii) Deferred Cancellation: The target thread can periodically check if it should terminate itself, allowing the target thread an opportunity to terminate itself in an orderly fashion. e.g. Pthread API.

In asynchronous cancellation, a thread may be cancelled in the middle of use of a resource (such as file updation). Therefore, cancelling a thread asynchronously may not free a necessary system-wide resource.

Deferred cancellation allows a thread to check if it should be cancelled at a point when it can safely be cancelled. Pthreads refer to such points as cancellation points.

3. Signal handling:

A signal is generated by the occurrence of a particular event. A generated signal is delivered to a process. Once signal is generated, it must be handled.

A signal may be received either synchronously or asynchronously, depending upon the source and the reason for the event being signalled.

Types of Signals:

1. Synchronous: signal is delivered to same process that performed the operation causing the signal e.g. illegal memory access, division by zero.

2. Asynchronous: signal is generated by an event external to a running process i.e. delivered to different process. e.g. Timer expire.

Handlers: There are two possible handlers to handle the signal.

(i) A default signal handler: Every signal has a default signal handler that is run by the kernel.

(ii) User defined signal handler: The default action may be overridden by a user-defined signal handler a function. The user-defined function is called to handle the signal rather than the default action.

Both synchronous and asynchronous signals may be handled in different ways. Some signals may be simply ignored; others may be handled by terminating the program. e.g. changing the size of a window, an illegal memory access.

Handling signals in a single threaded prgms is straight forward.

Different options for delivering signals:

1. Deliver the signal to the thread to which the signal applies - for synchronous signal.
2. Deliver the signal to every thread in the process
3. Deliver the signal to certain threads in the process e.g. UNIX (multithreaded.
4. Assign a specific thread to receive all signals for the process e.g. Solaris2.

4. <u>Thread Pools</u>: Whenever the server receives a request, it creates a separate thread to service the request. Some potential problems are:

1) Amount of time required to create the thread
2) Thread will be discarded once it has completed its work.
3) Number of threads may be very large. Unlimited threads could exhaust system resources, such as CPU time or memory ...

Above problems can be solved by thread pools.

- A number of threads can be created at process startup and placed into a pool.
- When server receives a request, it awakens a thread from this pool. If thread is available, the request can be passed to thread for service
- When thread completes its service, it returns the to the pool awaiting more work ...

~~If the thread completes its service, it returns to~~

- If the pool contains no available thread, the server waits until ~~one~~ thread becomes free.

<u>Benefits of thread</u>:

1) It is faster to service a request with an existing thread than waiting to create a thread.
2) A thread pool limits the number of threads that exist in system.

<u>Thread - Specific Data</u>

Threads belonging to a process share the data of the process. This sharing of data provides one of the benefits of multithreaded programming.

In some cases, each thread may need its own copy of certain data, such data are thread-specific data e.g. in a transaction processing system, each transaction may be assigned a unique identifier. To associate each thread with its unique identifier, thread-specific data is used.

<u>Pthreads</u>: Pthreads refer to the POSIX standard defining an API for thread creation and synchronization. This is a specification for thread behaviour, not an implementation.

Pthreads is a user level library. Libraries implementing the Pthreads specification are restricted to UNIX-based systems such as Solaris 2.

• All Pthread programs must include the <u>pthread.h</u> header file. The statement <u>pthread_t tid</u> declares the identifier for the thread created.

• Each thread has a set of attributes including stack size and scheduling information. The <u>pthread_attr_t attr</u> declaration represents the attributes for the thread.

• Attributes can be set in the function call <u>pthread_attr_init(&attr)</u>.

• A separate thread is created with the <u>pthread_create</u> function call in the following form.

pthread_create(&tid, &attr, runner, argv[1])

• After the creation of a separate thread, program has two threads: the initial thread in main and thread performing the summation function call in the runner function. After creating the second thread the main thread will wait for the runner thread to complete by calling the <u>pthread_join</u> function.

• The runner thread will complete when it calls the function <u>pthread_exit</u>.

Java threads:

Java provides ~~spo~~ support at the language level for the creation and management of threads. ~~Java~~ threads can not be classified as either user-level ~~library~~ or kernel-~~models~~ level because java threads are managed by the Java Virtual Machine (JVM) not by a user-level library or kernel.

All Java programs comprise at least a single thread of control. Even a simple java program consisting ~~as~~ of only a main method runs as a single thread in the JVM. Java provides the commands that allow the developer to create and manipulate additional threads of control within the program.

Thread Creation:

Thread can be created by creating a new class that is derived from the Thread class and to override the run method of the Thread class.

```
class Summation extends Thread
{
   :
}
public class ThreadTester
{
   :
   Summation thrd = new Summation (. . .);
   thrd.start();
   :
}
```

An object of the derived class will run as a separate thread of control in the JVM. However, creating an object that is derived from the Thread class does not specifically create the new thread; rather, it is start method that actually creates the new thread

Calling the start method for the new object does two things:

1. It allocates memory and initializes a new thread in the JVM.
2. It calls the run method, making the thread eligible to be run by the JVM.

When the summation program runs, two threads are created by the JVM:

① The first thread is associated with the application and starts execution at the main method.

② The second thread is the summation thread that is created explicitly with the start method. The summation thread begins execution in its run method. The thread terminates when it exits from its run method

The JVM and the Host operating system:

The typical implementation of the JVM is on the top of a host OS. This setup allows the JVM to hide the implementation details of the underlying OS and to provide a consistent, abstract ~~in~~ environment that allows Java programs to operate on any platform that supports a JVM. The specification for the JVM does not indicate how Java threads are to be mapped to the underlying OS, instead leaving that decision to the particular implementation of the JVM.

Windows 95/98/NT/2000 use the one to one-model, therefore, each Java thread for a JVM running on these OS maps to a kernel thread.

Solaris 2 initially implemented the JVM using the many-to-one model (called green threads).

Java ver 1.1 with Solaris 2.6 was implemented using the many-to-many model.

OS

Unit-3 (Chapter 6)

CPU Scheduling :- CPU Scheduling is the task of selecting a waiting process from the ready queue and allocating the CPU to it. Thus, Objective of CPU scheduling is maximize CPU utilization.

CPU - I/O Burst Cycle :

Process execution consists of a cycle of CPU execution and I/O wait alternating between these two cycles. Process execution starts with CPU burst and ends with CPU burst.

Instructions } CPU Burst
Wait for I/O } I/O Burst
Instructions } CPU Burst
Wait for I/O } I/O Burst
Instructions } CPU Burst

An I/O-bound program have many very short CPU bursts. A CPU-bound program may have a few very long CPU bursts. Type of programs in a system helps to select the CPU-Scheduling algorithm.

CPU Scheduler :- This is also known as short term scheduler. It selects the process from ready queue and and allocates the CPU for execution on the basis of some scheduling algorithm.

The ready queue may be implemented as a FIFO queue, a priority queue, a tree or an ordinary

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linked list. The records in the queue are PCBs of the process.

Dispatcher: The module dispatcher gives control of the CPU to the process selected by the short-term scheduler. This function involves:

- Switching context
- Switching to user mode
- Jumping to the proper location in the user program to restart that program.

The time taken by dispatcher to stop one process and starts another process is known as dispatch latency.

~~Scheduling Criteria~~:

Non-preemptive Scheduling:
When a process switches from running state to waiting state due to either some I/O services or need of OS service. IF voluntarily surrenders the control of CPU and it can not be forced to leave the ownership of the processor when a higher-priority process comes for execution. This is followed in some OS like windows 3.1, Apple Macintosh OS.

Preemptive Scheduling: A running process may be replaced by another process on the basis of priority, shorter ~~burst~~ CPU burst etc. Preemption necessiates more frequent execution of the scheduler. Preemptive scheduling is more responsive, but it imposes higher overhead, since each ps thus it incurs a cost.

Scheduling Criteria :

Different CPU-Scheduling have different properties and may favour one class of processes over another. There can be many criteria to choose one particular scheduling algorithm for particular situation.

1. CPU-utilization :- Processor should be busy as much as possible giving CPU utilization on higher side

2. Throughput :- Throughput refers to the amount of work completed in a unit of time. The higher the number, the more work is being done by the System.

3. Turnaround time : It is time required from the submission of job to completion of job. It is the sum of execution time and waiting time. Scheduling selection should reduce the turn around time.

4. Waiting time : It is time spent waiting in a ready queue. It should be as less as possible.

5. Response time : It is time required from the submission of a request until the first response is produced.

Schedulers try to maximise the average performance of a system by maximising CPU utilization and throughput, by minimising the turn around time, waiting time, response time.

Scheduling Algorithms :

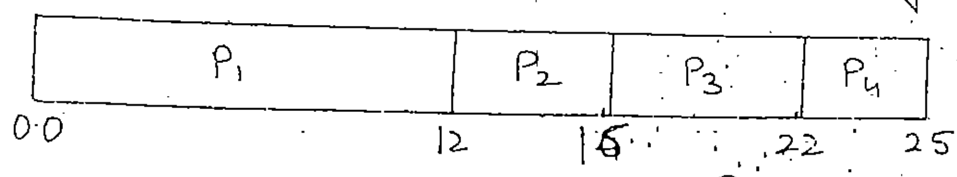
1. First-Come, first-served Algorithm : (or First in first out)

It is the simplest algorithm to implement. When a process becomes ready, it joins ready queue at the tail, when CPU is free, process at the head of the queue gets CPU for execution. The average waiting time under the FCFS policy is quite long. It is Non-preemptive i.e. process starts execution, it leaves CPU voluntarily only.

Example:

Process	Burst time (m s.)
P_1	12
P_2	4
P_3	6
P_4	3

All processes have arrived at 0.0 time in order of P_1, P_2, P_3, P_4



Gantt. Chart

Waiting time for $P_1 = 0$

" " " $P_2 = 12$

" " " $P_3 = 16$

" " " $P_4 = 22$

Average Waiting time $= (0+12+16+22)/4 = 50/4$
$= 12.5$ ms

Average turn around time $= (12+16+22+25)/4 = 18.75$ ms

Convoy effect : If all the processes wait for one big process to get off the CPU, it is known as convoy effect. FCFS policy suffers due to this effect.

× 2 **Shortest Job-first Scheduling:** (SJF) When the CPU is available it is assigned to the process that has the smallest next CPU burst. If two processes have the same length CPU burst, FCFS scheduling is used to break the tie.

Difficulties in SJF: To know the length of next CPU burst, it is very difficult, thus it can not be implemented at the level of short-term scheduling. It is good policy for long-term scheduling because user can specify process time limit while submitting the job. Only prediction of CPU burst time is possible on the basis of previous burst time of same type or same process.

Types of SJF:

Nonpreemptive SJF: It allows the currently running process to finish its CPU burst irrespective of burst time of newly arrived processes in the system.

Example:

Process	Burst time
P_1	6
P_2	9
P_3	5
P_4	3

All processes arrive at same time i.e. 0.0 in order of P_1, P_2, P_3, P_4

P_4	P_3	P_1	P_2
0 – 3	3 – 8	8 – 14	14 – 23

Gantt Chart.

Waiting time for $P_1 = 8$
" " " $P_2 = 14$
" " " P_3 3
" " " $P_4 = 0$

Average Waiting time = $(8+14+3+0)/4 = 6.25$ ms
Average Turnaround Time = $(14+23+8+3)/4 = 12$ ms

(SRTF) or Preemptive SJF

<u>Preemptive SJF or Shortest-remaining time first</u> –
When a new process arrives at the ready queue, the burst time of new process is compared with remaining burst time of running process. If new process burst time is less than remaining burst time of running process, running process will be preempted and new process will start executing.

<u>Example:</u>

Process	Arrival time	Burst time
P_1	0	8
P_2	1	5
P_3	3	10
P_4	4	3

At time 0 : only P_1 → P_1 runs

At time 1 : $\left.\begin{array}{l} P_1 = 7 \\ P_2 = 5 \end{array}\right\}$ → P_2 runs

At time 3 : $\left.\begin{array}{l} P_1 = 7 \\ P_2 = 3 \\ P_3 = 10 \end{array}\right\}$ → P_2 runs

~~At time 4~~ :

At time 4: $P_1 = 7$, $P_2 = 2$, $P_3 = 10$, $P_4 = 3$ } P_2 runs then P_4, P_1, P_3

Sequence. $P_1 \rightarrow P_2 \rightarrow P_4 \rightarrow P_1 \rightarrow P_3$
time (1) (5) (3) (7) (10)

~~Average Waiting time~~

P_1	P_2	P_4	P_1	P_3
0–1	1–6	6–9	9–16	16–26

Gantt Chart

Average Waiting time $= [(9-1-0) + (1-1) + (16-3) + (6-4)]/4$
$= 5.75$ ms

Average turn around time:
$= [(16-0) + (6-1) + (26-3) + (9-4)]/4$
$= 12.25$ ms

* 3. Priority Scheduling :- A priority is associated with each process, and the CPU is allocated to the process with the highest priority. Equal priority processes are scheduled in FCFS order.

Priorities can be defined internally on the basis of some factors such as time limits, memory requirements, no. of open files etc. Priorities can be defined externally also on the basis of factors such as importance of type of process, payable process, processes belonging to different processes

Problem in Priority Scheduling:

Indefinite blocking (or Starvation): In a heavily loaded system, a steady stream of higher priority processes can prevent a low-priority process from ever getting the CPU.

Solution is aging, a technique of gradually increasing the priority of processes that wait in the system for a long time.

Types of Priority Scheduling:

Non-preemptive: This algorithm puts the new process at the ~~head~~ ready queue. When running process finishes execution or terminates itself than only highest priority process from ready queue will ~~be~~ sent for execution.

Preemptive: The priority of newly arrived ~~queue~~ process is compared with running process. If the priority of newly arrived process is higher than currently running process, the process is preempted and new process gets CPU for execution.

Example for Nonpreemptive priority Scheduling:

Process	Burst time	Priority
P_1	9	3
P_2	1	1
P_3	2	2
P_4	4	4

All the processes arrived at time 0.0 in order of P_1, P_2, P_3, P_4.

P2	P3	P1	P4
0–1	1–3	3–12	12–16

0 1 3 12 16

Avg. W.T. = $(3 + 0 + 1 + 12)/4 = 4$

Avg. Turnaround time $= (12 + 1 + 3 + 16)/4 = 8$

Example for Preemptive priority Scheduling :

Process	Burst time	Priority	Arrival time
P_1	8	3	0.0
P_2	2	1	1.0
P_3	3	2	2.0
P_4	5	4	3.0

P1	P2	P3	P1	P4
0–1	1–3	3–6	6–13	13–18

0 1 3 6 13 18

Avg. W.T $= [(6-1-0) + (1-1) + (3-2) + (13-3)]/4$

$= 4$

Avg. Turn around time $= [(13-0) + (3-1) + (6-2) + (18-3)]/4$

$= 8.5$

4. Round Robin Scheduling:

It is a preemptive scheduling specially designed for time-sharing system. The processor time is divided into time slices or time quanta, which are allocated to processes. No process can run for more than one time slice when there are others waiting in the ready queue. Ready queue is implemented as FIFO queue of processes. New processes are added to the tail of the ready queue.

Each process executes either equal to one time quantum and is preempted and sent to tail of the queue. (Or) if burst time is less than time quantum, it finishes execution and exits.

Performance of RR algorithm depends on the size of time quantum. If the time quantum is very large, RR is same as FCFS policy. If the time quantum is very small, ~~RR is~~ overhead in context switching will be more.

Example:

Process	Burst time
P_1	12
P_2	6
P_3	4

Time quantum = 2

All processes arrived at time 0.0 ~~&~~ in the order of P_1, P_2, P_3

P_1	P_2	P_3	P_1	P_2	P_3	P_1	P_2	P_1	P_1	P_1

0 2 4 6 8 10 12 14 16 18 20 22

$$\text{Avg W.T.} = [(20-10)+(14-4)-(10-2)]/3$$
$$= 9.33$$

$$\text{Avg Turnaround time} = (22+16+12)/3 = 16.66$$

5. Multilevel Queue Scheduling:

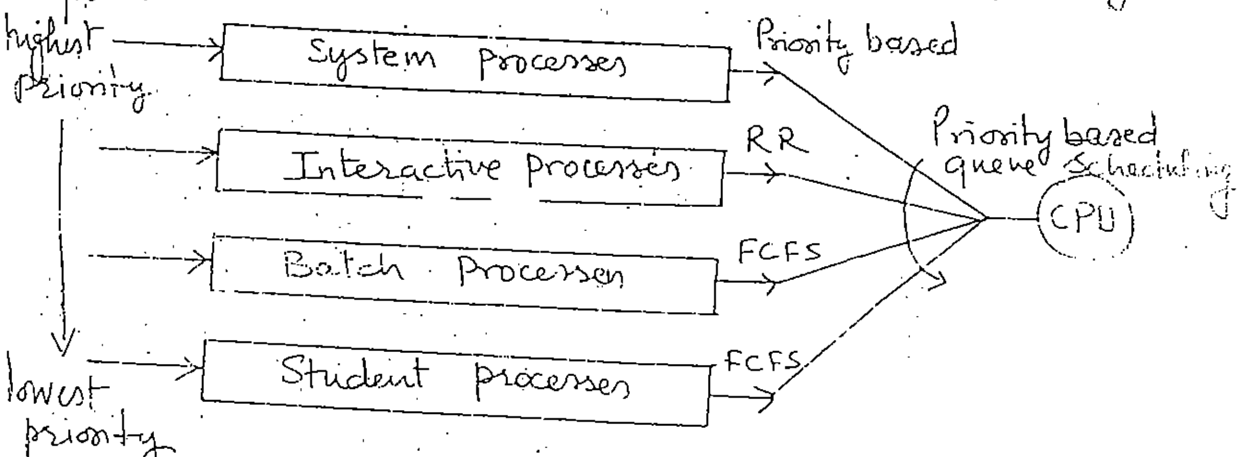
No single CPU Scheduling is proper with a mixed system with time-critical ~~systems~~ processes, ~~a multitude of~~ interactive processes, very long non-interactive jobs. One approach is to combine several scheduling algorithms.

A ready queue is partitioned into several separate queues. A process is permanently assigned to one queue based on some attribute of process such as memory size, process priority or process type. Each queue has its own scheduling algorithm. There must be scheduling among the queues, which is commonly implemented as fixed-priority preemptive scheduling.

For example ① Separate queues may be used for foreground and background processes. The foreground queue may be scheduled by an RR algorithm, while the background queue is scheduled by an FCFS algorithm. Foreground queue may have absolute priority over the background queue.

When the higher priority queues become empty, a lower priority queue is serviced. A low priority process ~~may be~~ is preempted by a higher priority ~~arrived~~ queue due to new arrival.

② If four queues are there on the basis of process type, each having one scheduling policy. Each queue has absolute priority over lower-priority queues.



Queue's scheduling can be implemented on the basis of time slice. Each queue gets a certain portion of CPU time, which can be scheduled among the various processes in its queue.

6. Multilevel feedback Queue Scheduling:

This algorithm allows a process to move between queues. If a process uses too much CPU time, it will be moved to a lower-priority queue. I/O bound and interactive processes may continue in higher priority queues. If a process waits too long in a lower priority queue, it may be moved to a higher-priority queue. This is aging which prevents starvation.

~~For example:~~ Performance of this algorithm depends on the following parameters:

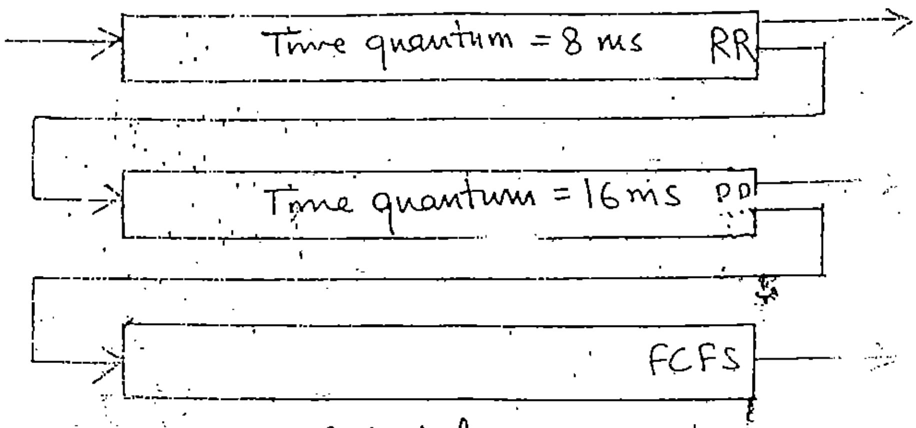
1. The no. of queues.
2. The scheduling algorithm for each queue
3. The method to determine when to upgrade a process to a higher priority queue.
4. The method to determine when to demote a process to a lower priority queue.

This is most general and complex algorithm and can be configured to match a specific system.

For example:

If this algorithm is implemented with three queues The scheduler first executes all processes in queue 0 then 1 and then 2 *A process that arrives for queue 0 will preempt a process in queue 1 and so on. A process in queue 0 gets a time quantum of 8 ms. If a process does not finish in 8 ms it again joins tail of queue 1 and so on. Thus the process with short CPU burst will get higher priority. (Fig next page)

* Queue 0 and 1 Scheduling scheme is RR and Queue 2 has FCFS.



7. Multiple processor Scheduling :

In a homogeneous multiprocessor environment (identical processors having same functionalities), two approaches can be followed

1) Separate queue for each processor : It is possible to provide a separate queue for each processor. But one processor can be idle with an empty queue while another processor may be very busy with highly loaded queue.

2. A common ready queue : All processes go into a queue and are scheduled onto any available processor. For such implementation, two approaches can be followed.

(i) Self - Scheduling :

Each processor is self-scheduling and examines the common ready queue and selects a process to execute. In this scheme, multiple processors may try to access and update a common data structure. We must ensure that processors do not choose the same process.

(ii) Master - Slave Structure : One processor acts as scheduler for other processors which is called master processor. In some systems, master processor may have all scheduling decisions, I/O processing and other activities. The others processors only execute user code. Thus one processor accesses the system data structures avoiding the need for data sharing. But it may lead to bottleneck as one CPU is performing all the operations.

8. Real-time Scheduling:

Hard real-time system: In hard real-time system, a critical task should be completed within a guaranteed amount of time or at a particular time. A process is submitted with requirement of amount of time needed to finish I/O.

Either scheduler can reject the process or admit the process guaranteeing that the process will complete on time. This is known as resource reservation. This guarantee is not possible with general purpose system. Thus, the hard real-time systems are composed of special-purpose software running on hardware dedicated to their critical processes. ~~and~~

Soft real-time systems: Here, critical processes are getting priority higher than the priority of less important processes. Thus, the system should have the priority scheduling algorithm, and the priority of real-time processes must not degrade over time. Aging of general processes should be disallowed.

The dispatch latency must be small. The smaller the latency, the faster a real-time process can start execution.

Some system calls are comple and I/O deices are slow ~~which~~ and OS is forced to wait for system

call to complete or for an I/O block to take place before doing a context switch.
<u>Solution</u>: ① System calls can be preemptible to keep dispatch latency low. Preemption points can be inserted at safe locations where presence of ready real process is checked. Safe points are those where kernel data structures are not being modified.
② All kernel data structures must be protected through the use of various synchronization mechanism. Thus, kernel data structure can be preemptible, because high priority process can not ~~modified~~ modify the data structure if low priority process is modifying the data structure.
Then, high priority process has to wait for longer for lower priority process which is known as priority inversion. This problem can be solved by priority-inheritance protocol, in which all the low priority processes while accessing data structure inherit the high priority. Once they finish, they acquire their original priority.

Problems

Q.1. 4 batch jobs P_1, P_2, P_3, P_4 arrive at a computer center at most the same order. The estimated running times are 10, 8, 2, 4 ms. The priorities are 3, 4, 1, 2. Time quantum is 2 ms. Draw Gantt Chart and compute Avg. waiting and avg. turn around time for following algorithms:
(i) FCFS, (ii) SJF (~~preemptive or~~ non preemptive)
(iii) Priority and (iv) RR.

Solution:

FCFS:

Process	Burst time	Priority
P_1	10	3
P_2	8	4
P_3	2	1
P_4	4	2

P_1	P_2	P_3	P_4
0	10	18	20 – 24

Avg. WT = $(0+10+18+20)/4 = 12$

Avg TAT = $(10+18+20+24)/4 = 18$

SJF:

P_3	P_4	P_2	P_1
0	2	6	14 – 24

Avg. WT $= (14+6+0+2)/4$
$= 5.5$

Avg. TAT $= (24+14+2+6)/4$
$= 11.5$

4a

Priority based:

P3	P4	P1	P2

0 2 6 16 24

Avg WT $= (6 + 16 + 0 + 2)/4 = 6$
Avg TAT $= (16 + 24 + 2 + 6)/4 = 12$

Round Robin

P1	P2	P3	P4	P1	P2	P4	P1	P2	P1	P2	P1

0 2 4 6 8 10 12 14 16 18 20 22 24

Avg WT $= [(22-8) + (20-6) + 4 + (12-2)]/4$
$= (14 + 14 + 4 + 10)/4$
$= 10.5$

Avg TAT $= (24 + 22 + 6 + 12)/4$
$= 16.5$

Q.2. The following jobs arrive at times indicated, each job will run listed amount of time

Jobs	Arrival Time	Burst time	Priority
1	0.0	8	2
2	0.4	4	1
3	1.0	2	3

Compute Avg Waiting time and Average Turn around time

Solution

FCFS

J1	J2	J3	J2	J1

0 0.4

J-1	J-2	J-3

0.0 8 12 14

Avg WT $= [(0-0) + (8-.4) + (12-1.0)]/3 = 6.2$
Avg TAT $= [(8-0) + (12-.4) + (14-1.0)]/3 = 10.86$

SJF Nonpreemptive

J-1	J-3	J-2
0.0 – 8	8 – 10	10 – 14

Avg WT $= [(0-0) + (10-.4) + (8-1.0)]/3 = 5.53$

Avg TAT $= [(8-0) + (14-.4) + (10-1.0)]/3 = 10.2$

SJF preemptive

J-1	J-2	J-3	J-2	J-1
0 – .4	.4 – 1.0	1.0 – 3.0	3.0 – 6.4	6.4 – 14.0

Avg WT $= [(6.4 - .4 - 0) + (3.0 - .6 - .4) + (1-1)]/3$
$= 2.66$

Avg TAT $= [(14-0) + (6.4-.4) + (3.0-1)]/3 = 7.33$

Round Robin

J-1	J-2	3	1	2	3	1	2	1	2	1	1	1	1
0 – 1	1 – 2	2 – 3	3 – 4	4 – 5	5 – 6	6 – 7	7 – 8	8 – 9	9 – 10	10 – 11	11 – 12	12 – 13	13 – 14

Avg WT $= [(13-7-0) + (9-3-.4) + (5-1-1)]/3 = 4.86$

Avg TAT $= [(14-0) + (10-.4) + (6-1)]/3 = 9.53$

Priority (Nonpreemptive)

J-1	J-2	J-3
0 – 8	8 – 12	12 – 14

Avg WT $= [(0-0) + (8-.4) + (12-1)]/3 =$ [illegible]2

Avg TAT $= [(8-0) + (12-.4) + (14-1)]/3 =$ [illegible]86

Priority (Preemptive)

J-1	J-2	J-1	J-3
0 – .4	.4 – 4.4	4.4 – 12.0	12.0 – 14

Avg WT $= [(4.4 - .4 - 0) + (4 - .4) + (12 - 1)]/3 = 5.0$

Avg TAT $= [(12-0) + (4.4-.4) + (14-1)]/3 = 9.66$