Q - 1 : DEFINE PROCESS SYNCHRONIZATION AND EXPLAIN THE CRITICAL SECTION PROBLEM.

ANS => **Process Synchronization** is the task of coordinating the execution of processes in a way that no two processes can have access to the same shared data and resources.

What is Critical Section Problem?

A critical section is a segment of code which can be accessed by a signal process at a specific point of time. The section consists of shared data resources that required to be accessed by other processes.

- The entry to the critical section is handled by the wait() function, and it is represented as P().
- The exit from a critical section is controlled by the signal() function, represented as V().

In the critical section, only a single process can be executed. Other processes, waiting to execute their critical section, need to wait until the current process completes its execution.

Rules for Critical Section

The critical section need to must enforce all three rules:

- **Mutual Exclusion:** Mutual Exclusion is a special type of binary semaphore which is used for controlling access to the shared resource. It includes a priority inheritance mechanism to avoid extended priority inversion problems. Not more than one process can execute in its critical section at one time.
- **Progress:** This solution is used when no one is in the critical section, and someone wants in. Then those processes not in their reminder section should decide who should go in, in a finite time.
- **Bound Waiting:** When a process makes a request for getting into critical section, there is a specific limit about number of processes can get into their critical section. So, when the limit is reached, the system must allow request to the process to get into its critical section.

Q - 2 : EXPLAIN SEMAPHORES WITH EXAMPLE.

ANS => **Semaphores** are integer variables that are used to solve the critical section problem by using two atomic operations, wait and signal that are used for process synchronization.

The definitions of wait and signal are as follows −

- Wait
  The wait operation decrements the value of its argument S, if it is positive. If S is negative or zero, then no operation is performed.

```
wait(S)
{
   while (S<=0);

   S--;
}
```

- Signal
  The signal operation increments the value of its argument S.

```
signal(S)
{
   S++;
}
```

Types of Semaphores

There are two main types of semaphores i.e. counting semaphores and binary semaphores. Details about these are given as follows −

- Counting Semaphores
  These are integer value semaphores and have an unrestricted value domain. These semaphores are used to coordinate the resource access, where the semaphore count is the number of available resources. If the resources are added, semaphore count automatically incremented and if the resources are removed, the count is decremented.
- Binary Semaphores
  The binary semaphores are like counting semaphores but their value is restricted to 0 and 1. The wait operation only works when the semaphore is 1 and the signal operation succeeds when semaphore is 0. It is sometimes easier to implement binary semaphores than counting semaphores.

Advantages of Semaphores

Some of the advantages of semaphores are as follows −

- Semaphores allow only one process into the critical section. They follow the mutual exclusion principle strictly and are much more efficient than some other methods of synchronization.
- There is no resource wastage because of busy waiting in semaphores as processor time is not wasted unnecessarily to check if a condition is fulfilled to allow a process to access the critical section.
- Semaphores are implemented in the machine independent code of the microkernel. So they are machine independent.

Disadvantages of Semaphores

Some of the disadvantages of semaphores are as follows −

- Semaphores are complicated so the wait and signal operations must be implemented in the correct order to prevent deadlocks.
- Semaphores are impractical for last scale use as their use leads to loss of modularity. This happens because the wait and signal operations prevent the creation of a structured layout for the system.
- Semaphores may lead to a priority inversion where low priority processes may access the critical section first and high priority processes later.

Q - 3 : EXPLAIN CLASSICAL PROBLEMS OF SYNCHRONIZATION.

ANS =>

1. Bounded-buffer (or Producer-Consumer) Problem,

2. Dining-Philosophers Problem,

3. Readers and Writers Problem,

4. Sleeping Barber Problem

Bounded-buffer (or Producer-Consumer) Problem:
Bounded Buffer problem is also called producer consumer problem. This problem is generalized in terms of the Producer-Consumer problem. Solution to this problem is, creating two counting semaphores "full" and "empty" to keep track of the current number of full and empty buffers respectively. Producers produce a product and consumers consume the product, but both use of one of the containers each time.

Dining-Philosophers Problem:
The Dining Philosopher Problem states that K philosophers seated around a circular table with one chopstick between each pair of philosophers. There is one chopstick between each philosopher. A philosopher may eat if he can pickup the two chopsticks adjacent to him. One chopstick may be picked up by any one of its adjacent followers but not both. This problem involves the allocation of limited resources to a group of processes in a deadlock-free and starvation-free manner.

Readers and Writers Problem:
Suppose that a database is to be shared among several concurrent processes. Some of these processes may want only to read the database, whereas others may want to update (that is, to read and write) the database. We distinguish between

these two types of processes by referring to the former as readers and to the latter as writers. Precisely in OS we call this situation as the readers-writers problem. Problem parameters:

- One set of data is shared among a number of processes.
- Once a writer is ready, it performs its write. Only one writer may write at a time.
- If a process is writing, no other process can read it.
- If at least one reader is reading, no other process can write.
- Readers may not write and only read.

Sleeping Barber Problem:
Barber shop with one barber, one barber chair and N chairs to wait in. When no customers the barber goes to sleep in barber chair and must be woken when a customer comes in. When barber is cutting hair new customers take empty seats to wait, or leave if no vacancy.

Q – 4 : SHORT NOTE ON DEAD LOCK.

ANS => A Deadlock is a situation where each of the computer process waits for a resource which is being assigned to some another process. In this situation, none of the process gets executed since the resource it needs, is held by some other process which is also waiting for some other resource to be released.

Let us assume that there are three processes P1, P2 and P3. There are three different resources R1, R2 and R3. R1 is assigned to P1, R2 is assigned to P2 and R3 is assigned to P3.

After some time, P1 demands for R1 which is being used by P2. P1 halts its execution since it can't complete without R2. P2 also demands for R3 which is being used by P3. P2 also stops its execution because it can't continue without R3. P3 also demands for R1 which is being used by P1 therefore P3 also stops its execution.

In this scenario, a cycle is being formed among the three processes. None of the process is progressing and they are all waiting. The computer becomes unresponsive since all the processes got blocked.

Necessary conditions for Deadlocks

1. **Mutual Exclusion**

   A resource can only be shared in mutually exclusive manner. It implies, if two process cannot use the same resource at the same time.

2. **Hold and Wait**

   A process waits for some resources while holding another resource at the same time.

3. **No preemption**

   The process which once scheduled will be executed till the completion. No other process can be scheduled by the scheduler meanwhile.

4. **Circular Wait**

   All the processes must be waiting for the resources in a cyclic manner so that the last process is waiting for the resource which is being held by the first process.

Q – 5 : EXPLAIN METHODS FOR HANDLING DEADLOCKS.

ANS =>

1. Deadlock Ignorance

Deadlock Ignorance is the most widely used approach among all the mechanism. This is being used by many operating systems mainly for end user uses. In this approach, the Operating system assumes that deadlock never occurs. It simply ignores deadlock. This approach is best suitable for a single end user system where User uses the system only for browsing and all other normal stuff.

There is always a tradeoff between Correctness and performance. The operating systems like Windows and Linux mainly focus upon performance. However, the performance of the system decreases if it uses deadlock handling mechanism all the time if deadlock happens 1 out of 100 times then it is completely unnecessary to use the deadlock handling mechanism all the time.

In these types of systems, the user has to simply restart the computer in the case of deadlock. Windows and Linux are mainly using this approach.

2. Deadlock prevention

Deadlock happens only when Mutual Exclusion, hold and wait, No preemption and circular wait holds simultaneously. If it is possible to violate one of the four conditions at any time then the deadlock can never occur in the system.

The idea behind the approach is very simple that we have to fail one of the four conditions but there can be a big argument on its physical implementation in the system.

3. Deadlock avoidance

In deadlock avoidance, the operating system checks whether the system is in safe state or in unsafe state at every step which the operating system performs. The process continues until the system is in safe state. Once the system moves to unsafe state, the OS has to backtrack one step.

In simple words, The OS reviews each allocation so that the allocation doesn't cause the deadlock in the system.

4. Deadlock detection and recovery

This approach let the processes fall in deadlock and then periodically check whether deadlock occur in the system or not. If it occurs then it applies some of the recovery methods to the system to get rid of deadlock.

Q – 6 : HOW TO PREVENT , AVOIDANCE AND DETECTION RECOVERY FROM DEADLOCK.

ANS =>

Deadlock Prevention

Deadlock prevention algorithms ensure that at least one of the necessary conditions (Mutual exclusion, hold and wait, no preemption and circular wait) does not hold true. However most prevention algorithms have poor resource utilization, and hence result in reduced throughputs.

Mutual Exclusion

Not always possible to prevent deadlock by preventing mutual exclusion (making all resources shareable) as certain resources are cannot be shared safely.

Hold and Wait

We will see two approaches, but both have their disadvantages.

A resource can get all required resources before it start execution. This will avoid deadlock, but will result in reduced throughputs as resources are held by processes even when they are not needed. They could have been used by other processes during this time.

Second approach is to request for a resource only when it is not holing any other resource. This may result in a starvation as all required resources might not be available freely always.

No preemption

We will see two approaches here. If a process request for a resource which is held by another waiting resource, then the resource may be preempted from the other waiting resource. In the second approach, if a process request for a resource which are not readily available, all other resources that it holds are preempted.

The challenge here is that the resources can be preempted only if we can save the current state can be saved and processes could be restarted later from the saved state.

Circular wait

To avoid circular wait, resources may be ordered and we can ensure that each process can request resources only in an increasing order of these numbers. The algorithm may itself increase complexity and may also lead to poor resource utilization.

Deadlock Recovery

Once a deadlock is detected, you will have to break the deadlock. It can be done through different ways, including, aborting one or more processes to break the circular wait condition causing the deadlock and preempting resources from one or more processes which are deadlocked.

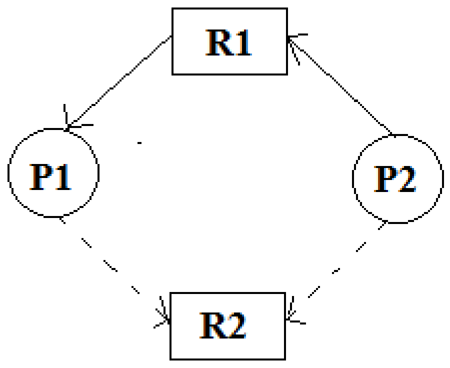
Deadlock avoidance

As you saw already, most prevention algorithms have poor resource utilization, and hence result in reduced throughputs. Instead, we can try to avoid deadlocks by making use prior knowledge about the usage of resources by processes including resources available, resources allocated, future requests and future releases by processes. Most deadlock avoidance algorithms need every process to tell in advance the maximum number of resources of each type that it may need. Based on all these info we may decide if a process should wait for a resource or not, and thus avoid chances for circular wait.

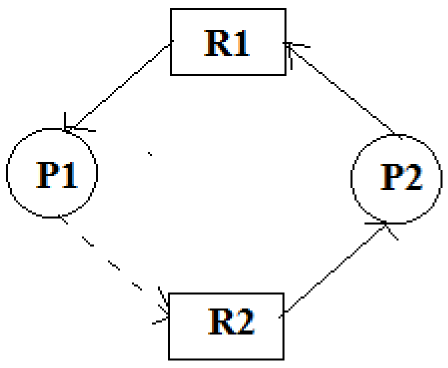
If a system is already in a safe state, we can try to stay away from an unsafe state and avoid deadlock. Deadlocks cannot be avoided in an unsafe state. A system can be considered to be in safe state if it is not in a state of deadlock and can allocate resources upto the maximum available. A safe sequence of processes and allocation of resources ensures a safe state. Deadlock avoidance algorithms try not to allocate resources to a process if it will make the system in an unsafe state. Since resource allocation is not done right away in some cases, deadlock avoidance algorithms also suffer from low resource utilization problem.

A resource allocation graph is generally used to avoid deadlocks. If there are no cycles in the resource allocation graph, then there are no deadlocks. If there are cycles, there may be a deadlock. If there is only one instance of every resource, then a cycle implies a deadlock. Vertices of the resource allocation graph are resources and processes. The resource allocation graph has request edges and assignment edges. An edge from a process to resource is a request edge and an edge from a resource to process is an allocation edge. A calm edge denotes that a request may be made in future and is represented as a dashed line. Based on calm edges we can see if there is a chance for a cycle and then grant requests if the system will again be in a safe state.

Consider the image with calm edges as below:



If R2 is allocated to p2 and if P1 request for R2, there will be a deadlock.



The resource allocation graph is not much useful if there are multiple instances for a resource. In such a case, we can use Banker’s algorithm. In this algorithm, every process must tell upfront the maximum resource of each type it need, subject to the maximum available instances for each type. Allocation of resources is made only, if the allocation ensures a safe state; else the processes need to wait. The Banker's algorithm can be divided into two parts: Safety algorithm if a system is in a safe state or not. The resource request algorithm make an assumption of allocation and see if the system will be in a safe state. If the new state is unsafe, the resources are not allocated and the data structures are restored to their previous state; in this case the processes must wait for the resource. *You can refer to any operating system text books for details of these algorithms.*