1. What are the chief characteristics of an SMP?

- All processors share the same memory and I/O devices.
- Processors run under a single operating system instance.
- Tasks can be scheduled on any processor (no processor affinity required).
- Processors communicate and synchronize through shared memory.
- Equal access to hardware resources (symmetry).

2. What are some of the potential advantages of an SMP compared with a uniprocessor?

i. Improved performance: Multiple processors can handle tasks in parallel.
ii. Fault tolerance: If one processor fails, others may continue working.
iii. Scalability: Additional processors can increase computing power.
iv. Better resource utilization: Tasks can be balanced across processors for efficiency.

3. What are some of the key OS design issues for an SMP?

- Synchronization: Managing access to shared resources to avoid conflicts.
- Scheduling: Distributing tasks efficiently among processors.
- Cache coherence: Ensuring consistency of data across multiple caches.
- Deadlock and race conditions: Avoiding issues when multiple processors access the same data.
- Load balancing: Preventing overload on some processors while others are idle.

4. What is the meaning of each of the four states in the MESI protocol?

- Modified: The cache line is updated and differs from main memory. Only one processor has it.
- Exclusive: The cache line is the same as in main memory and exists only in one cache.

- ❖ Shared: The cache line is the same as in memory and may exist in multiple caches.
- ❖ Invalid: The cache line is not valid; it has been modified or removed by another processor.

5. What are some of the key benefits of clustering?

- ✓ High availability: If one node fails, others can take over.
- ✓ Load balancing: Workload can be spread across multiple nodes.
- ✓ Scalability: More nodes can be added to increase capacity.
- ✓ Fault tolerance: Redundancy and failover mechanisms enhance reliability.
- ✓ Performance: Distributed processing improves overall system throughput.

6. What are the differences among UMA, NUMA, and CC-NUMA?

- UMA (Uniform Memory Access):
  - All processors access shared memory with equal latency.
  - Suitable for small-scale multiprocessor systems.
- NUMA (Non-Uniform Memory Access):
  - Each processor has its own local memory.
  - Access to local memory is faster than to remote memory.
  - More scalable than UMA, used in large systems.
- CC-NUMA (Cache-Coherent NUMA):
  - A NUMA system with a cache coherence protocol (e.g., MESI).
  - Ensures data consistency between processor caches.
  - Combines performance benefits of NUMA with programming simplicity.