1. Students working at individual PCs in a computer laboratory send their files to be printed by a server that spools the files on its hard disk, where it is buffered before being transferred to the printer.

a) Describe how the four conditions for deadlock apply to the spooling system if the disk space for the print spool is limited.

b) Which of the four conditions would be violated if a user could remove jobs from a spooling system?

2.

a) A system has two processes and three identical resources. Each process needs a maximum of two resources. Is deadlock possible?

b) Hence, with *p* processes each needing a maximum of *m* resources and a total of *r* resources available, what condition must hold to make the system deadlock free?

3. Consider three threads (`T1`, `T2`, and `T3`) that are created from the following code.

```
semaphore s1 = 1, s2 = 1, s3 = 1;

 void T1()                 void T2()                 void T3()
 {                         {                         {
      …                         …                         …
      semWait(s3);              semWait(s2);              semWait(s1);
      …                         …                         …
      semWait(s1);              semWait(s3);              semWait(s2);
      …                         …                         …
      semSignal(s3);            semSignal(s2);            semSignal(s1);
      …                         …                         …
      semSignal(s1);            semSignal(s3);            semSignal(s2);
 }                         }                         }

void main()
{
      parbegin (T1, T2, T3);
}
```

a) Show a case in which deadlock will occur.

b) Draw a resource allocation graph that shows the deadlock state.

c) Will deadlock occur if the order of resource requests of `T1` is changed as follows?

```
void T1()
{
     …
     semWait(s1);
     …
     semWait(s3);
     …
     semSignal(s3);
     …
     semSignal(s1);
}
```

Self-test

1. A set of processes is _____ when each process in the set is blocked awaiting an event that can only be triggered by another blocked process in the set.
A. spinlocked
B. stagnant
C. preempted
D. deadlocked

2. With _____ only one process may use a resource at a time and no process may access a resource unit that has been allocated to another process.
A. hold and wait
B. mutual exclusion
C. no preemption
D. circular wait

3. A closed chain of processes exists, such that each process holds at least one resource needed by the next process in the chain is the condition of _____ .
A. no preemption
B. mutual exclusion
C. circular wait
D. hold and wait

4. A condition of policy that must be present for a deadlock to be possible is _____.
A. mutual exclusion
B. hold and wait
C. no preemption
D. All of the above

5. Which of the following is an example of reusable resources?
A. Messages
B. Memory
C. Files
D. Interrupts

6. There must be a deadlock if the resource allocation graph contains a cycle.
A. True
B. False.