1. A system has 4 processes and 5 allocatable resource. The current allocation and maximum needs are as follows:

	Allocated	Maximum	Available
Process A	1 0 2 1 1	1 1 2 1 2	0 0 x 1 1
Process B	2 0 1 1 0	2 2 2 1 0	
Process C	1 1 0 1 0	2 1 3 1 0	
Process D	1 1 1 1 0	1 1 2 2 1	

What is the smallest value of x for which this a safe state.

Answer:

If x is 0, we have a deadlock immediately. If x is 1, process D can run to completion. When it is finished, the available vector is 1 1 2 2 1. Now A can run to complete, the available vector then becomes 2 1 4 3 2. Then C can run and finish, return the available vector as 3 2 4 4 2. Then B can run to complete. Safe sequence D A C B.

2. Textbook P368 Problem 9.13

A page-replacement algorithm should minimize the number of page faults. We can achieve this minimization by distributing heavily used pages evenly over all of memory, rather than having them compete for a small number of page frames. We can associate with each page frame a counter of the number of pages associated with that frame. Then, to replace a page, we can search for the page frame with the smallest counter.

a. Define a page-replacement algorithm using this basic idea. Specifically address these problems:
    1) What the initial value of the counter is
    2) When counters are increased
    3) When counters are decreased
    4) How the page to be replaced is selected
b. How many page faults occur for your algorithm for the following reference string, with four page frames?
   1,2,3,4,5,3,4,1,6,7,8,7,8,9,7,8,9,5,4,5,4,2
c. What is the minimum number of page faults for an optimal page-replacement strategy for the reference string in part b with four page frames?

Answer:

Note: There are many answers for this problem. As long as your basic idea is to associate with each page frame a counter of the number of pages associated with that frame. You can decrease this counter for some cases, you can increase it without decreasing, and you can also use some methods to decide the decreasing.

The following is a sample answer:

a. Define a page-replacement algorithmaddressing the problems of:
   1) Initial value of the counters—0.
   2) Counters are increased—whenever a new page is associated with that frame.
   3) Counters are decreased—whenever one of the pages associated with that frame is no longer required.
   4) How the page to be replaced is selected—find a frame with the smallest counter. Use FIFO for breaking ties.

b. 12 page faults

c. 11 page faults