HOMEWORK 4

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Question 1. a) Calculate the needs matrix. This is found by maximum demand minus current allocation.

TABLE 1. Problem 1 Needs Matrix

	R_a	R_b	R_c	R_d
P_0	0	3	0	0
P_1	0	7	5	0
P_2	1	0	0	2
P_3	0	0	2	0
P_4	0	6	4	2

b)

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available = [1, 5, 2, 0]
work = available
done = [0, 0, 0, 0, 0]
loop:
    if we find i such that:
        done[i] == 0
        need[i] <= work
        then
            work = work + allocation[i]
            done[i] = 1
    if done[i] = 1 for all i:
        return SAFE STATE
```

From the algorithm, we see P_0 has needs [0, 3, 0, 0] $\leq$ [1, 5, 2, 0] so set work = [1, 5, 3, 4]. Then P_2 has [1, 0, 0, 2] so set work = [2, 8, 8, 8]. Now P_1 has needs [0, 7, 5, 0] so work = [3, 8, 8, 8]. P_3 has [0, 0, 2, 0] and sets work = [3, 14, 11, 10]. Finally, P_4 has needs [0, 6, 4, 2] so work ends at [3, 14, 12, 14]. All processes have completed, so the system is in a safe state with process sequence P_0, P_2, P_1, P_3, P_4.

Question 2. Memory protection is important as it prevents different processes from modifying each other's memory space. For example, a C program could index an array out of bounds, or dereference a bad pointer, leading to modification of another program's memory. In a protected system, this is caught as a segmentation fault, but in an unprotected system, this could lead to undefined behaviour in the victim program.

Question 3. a) 130 b) does not map c) process 1, address 250
Question 4. 1. $[1, 2K-1]$, $[4K, 6K-1]$ 2.

(1) address $4500 = 4 \cdot 1024 + 404$; page 4 with offset 404

(2) address $8000 = 7 \cdot 1024 + 832$; page 7 with offset 832
(3) address $3000 = 2 \cdot 1024 + 952$; page 2 with offset 952
(4) address $1100 = 1 \cdot 1024 + 76$; page 1 with offset 76

We know from 1. that the first virtual address will cause a page fault. According to the reference string, page 7 was least recently used and will be replaced. Its new physical address is $1 \cdot 1024 + 404 = 1428$. The new table follows.

Table 2. Page table post-replacement

Virtual page	Physical page	Valid flag
0		no
1		no
2	2	yes
3	3	yes
4	1	yes
5		no
6	0	yes
7		no

The second reference, 8000, will also fault, and considering the reference string, page 6 will be replaced. Its physical address is $0 \cdot 1024 + 832 = 832$.

Table 3. Page table post-replacement 2

Virtual page	Physical page	Valid flag
0		no
1		no
2	2	yes
3	3	yes
4	1	yes
5		no
6		no
7	0	yes

Next, the third reference, 3000, will not fault as it does not fall in fault range. The fourth reference, 1100, will fault, and page 3 will be replaced. The physical address is $3\dot{1}024+76 = 3148$.

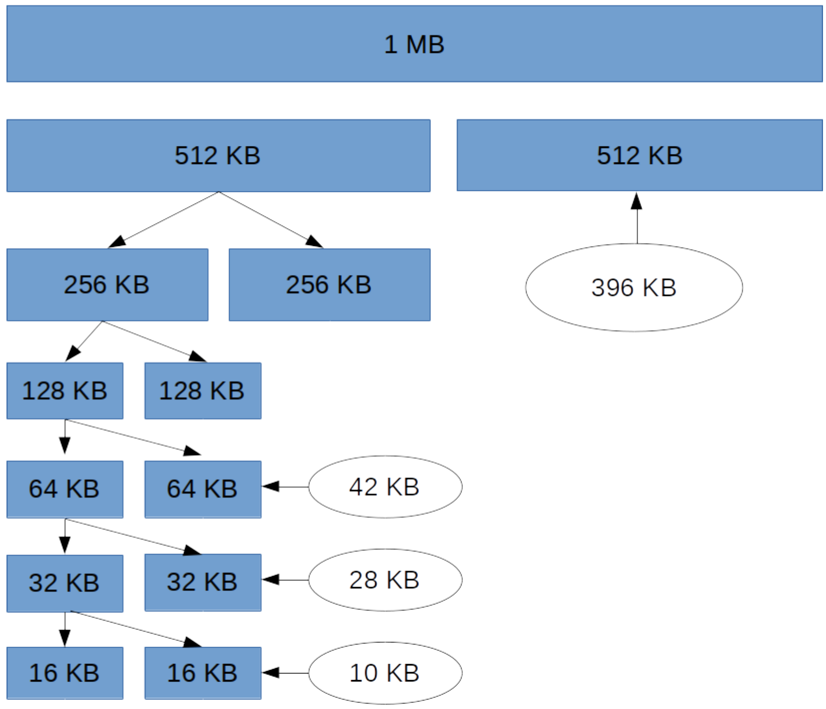
Question 5. 1. 2^{24} bytes = 16 MB. 2. Since offset length is 7, page size is $2^7 = 128$ bytes. 3.

$$\frac{2^{24}}{2^7} = 2^{17} = 128 \text{ KB}$$

4. 99% (normal access time) + 1% (fault access time) = 99% (99% (TLB hit access time) + 1% (TLB miss access time)) + 1% (fault access time) = 99% (99% (a+b)+1% (a+5b)) + 1% (a+4b+c)

$$\begin{aligned} &99\%(\text{normal access time}) + 1\%(\text{fault access time}) \\ &= 99\%(99\%(\text{TLB hit access time}) + 1\%(\text{TLB miss access time})) + 1\%(\text{fault access time}) \\ &= 99\%(99\%(a+b) + 1\%(a+5b)) + 1\%(a+4b+c) \end{aligned}$$

Question 6. a)



b) Because memory is allocated in powers of two, up to half of allocated memory could end up unnecessary. Here the total is

$$(512 - 396) + (64 - 42) + (32 - 28) + (16 - 10) = 148 \text{ KB}.$$

c) In this algorithm, free space holes are created by the same powers of two rule. The total is

$$16 + 128 + 256 = 400 \text{ KB}$$

so requested memory sizes greater than 256 KB cannot be granted.