

## Discussion Section: Week 10 (Solutions)

### Problem 1:

Consider a system in which the memory has the following hole sizes in the following memory order:  
1KB, 4 KB, 15 KB, 20 KB, 4 KB, 7 KB, 18 KB, 12 KB, 15 KB, 9 KB

You are given successive requests for program segments in the following order:  
10 KB, 5 KB, 3 KB, 2 KB, 19 KB, 9 KB, 24 KB, 10 KB.

For each of the following algorithms, show how the holes get filled for each of the above requests. If a particular request cannot be satisfied, you can skip it (but do mention which ones cannot be satisfied):

1. First fit:  
10 KB: 1, 4, **5**, 20, 4, 7, 18, 12, 15, 9  
5 KB: 1, 4, 20, 4, 7, 18, 12, 15, 9  
3 KB: 1, **1**, 20, 4, 7, 18, 12, 15, 9  
2 KB: 1, 1, **18**, 4, 7, 18, 12, 15, 9  
19 KB: Can't fit  
9 KB: 1, 1, **9**, 4, 7, 18, 12, 15, 9  
24 KB: Can't fit  
10 KB: 1, 1, 9, 4, 7, **8**, 12, 15, 9
2. Best fit:  
10 KB: 1, 4, 15, 20, 4, 7, 18, **2**, 15, 9  
5 KB: 1, 4, 15, 20, 4, **2**, 18, 2, 15, 9  
3 KB: 1, **1**, 15, 20, 4, 2, 18, 2, 15, 9  
2 KB: 1, 1, 15, 20, 4, 18, 2, 15, 9  
19 KB: 1, 1, 15, **1**, 4, 18, 2, 15, 9  
9 KB: 1, 1, 15, 1, 4, 18, 2, 15  
24 KB: Can't fit  
10 KB: 1, 1, **5**, 1, 4, 18, 2, 15
3. Worst fit:  
10 KB: 1, 4, 15, **10**, 4, 7, 18, 12, 15, 9  
5 KB: 1, 4, 15, 10, 4, 7, **13**, 12, 15, 9  
3 KB: 1, 4, **12**, 10, 4, 7, 13, 12, 15, 9  
2 KB: 1, 4, 12, 10, 4, 7, 13, 12, **13**, 9  
19 KB: Can't fit  
9 KB: 1, 4, 12, 10, 4, 7, **4**, 12, 13, 9  
24 KB: Can't fit  
10 KB: 1, 4, 12, 10, 4, 7, 4, 12, **3**, 9
4. Next fit:  
10 KB: 1, 4, **5**, 20, 4, 7, 18, 12, 15, 9  
5 KB: 1, 4, 20, 4, 7, 18, 12, 15, 9  
3 KB: 1, 4, **17**, 4, 7, 18, 12, 15, 9  
2 KB: 1, 4, **15**, 4, 7, 18, 12, 15, 9  
19 KB: Can't fit  
9 KB: 1, 4, **6**, 4, 7, 18, 12, 15, 9  
24 KB: Can't fit  
10 KB: 1, 4, 6, 4, 7, **8**, 12, 15, 9

**Problem 2:**

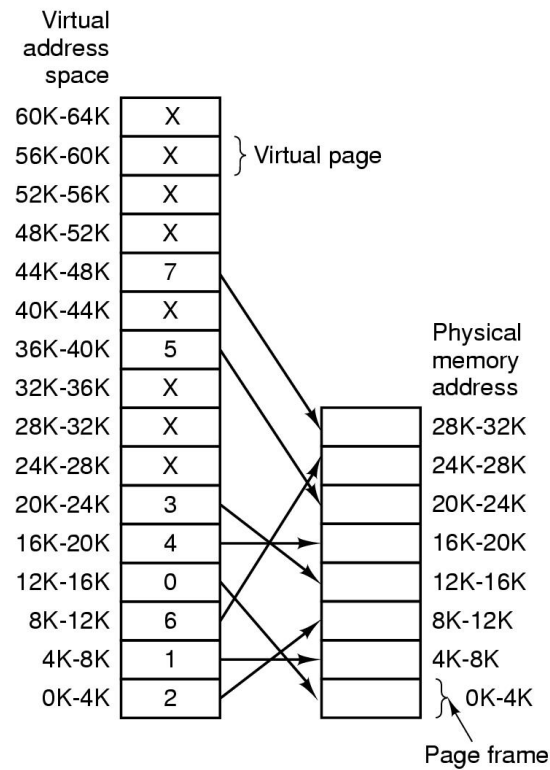
For each of the following decimal virtual addresses, compute the virtual page number and offset for a 4 KB page and for an 8 KB page: 20000, 32768, 60000.

4 KB =  $2^{12}$  B

8 KB =  $2^{13}$  B

Address	Page Number (4KB)	Offset (4KB)	Page Number (8KB)	Offset (8KB)
20000	4	3616	2	3616
32768	8	0	4	0
60000	14	2656	7	2656

**Problem 3:**



Consider the page table of the figure. Give the physical address corresponding to each of the following virtual addresses:

- (a) 29: Physical address:  $8K + 29 = 8221$
- (b) 4100: Physical address:  $4K + (4100 - 4K) = 4100$
- (c) 8300: Physical address:  $24K + (8300 - 8K) = 24684$

**Problem 4:**

A machine has 48 bit virtual addresses and 32 bit physical addresses. Pages are 8 KB. How many entries are needed for the page table?

$$\text{Page size} = 8 \text{ KB} = 2^{13} \text{ B}$$

$$\text{Offset} = 13 \text{ bits}$$

$$\# \text{ of virtual pages} = 2^{(48 - 13)} = 2^{35} = \# \text{ of entries in page table}$$

**Problem 5:**

Consider a machine such as the DEC Alpha 21064 which has 64 bit registers and manipulates 64-bit addresses. If the page size is 8KB, how many bits of virtual page number are there? If the page table used for translation from virtual to physical addresses were 8 bytes per entry, how much memory is required for the page table and is this amount of memory feasible?

$$\text{Page size} = 8 \text{ KB} = 2^{13} \text{ B}$$

$$\text{Offset} = 13 \text{ bits}$$

$$\text{Bits for virtual page number} = (64 - 13) = 51$$

$$\# \text{ of page table entries} = 2^{51}$$

$$\text{Size of page table} = 2^{51} * 8 \text{ B} = 2^{54} \text{ B} = 2^{24} \text{ GB}$$

**Problem 6:**

A computer with a 32-bit address uses a two-level page table. Virtual addresses are split into 9-bit top-level page table field, an 11 bit second-level page table field, and an offset. How large are the pages and how many are there in the address space?

$$\text{Offset} = 32 - 9 - 11 = 12 \text{ bits}$$

$$\text{Page size} = 2^{12} \text{ B} = 4 \text{ KB}$$

$$\text{Total number of pages possible} = 2^9 * 2^{11} = 2^{20}$$

**Problem 7:**

Fill in the following table:

Virtual Address (bits)	Page Size	# of Page Frames	# of Virtual Pages	Offset Length (bits)	Addressable Physical Memory
16	256 B = $2^8$	$2^2$	$2^8$	8	$2^{10} = 1 \text{ KB}$
32	1 MB = $2^{20}$	$2^4$	$2^{12}$	20	$2^{24} = 16 \text{ MB}$
32	1 KB = $2^{10}$	$2^8$	$2^{22}$	10	$2^{18} = 256 \text{ KB}$
64	16 KB = $2^{14}$	$2^{20}$	$2^{50}$	14	$2^{34} = 16 \text{ GB}$
64	8 MB = $2^{23}$	$2^{16}$	$2^{41}$	23	$2^{39} = 512 \text{ GB}$

**Problem 8:**

Fill in this table with the correct page evictions. Physical memory contains 4 pages.

Page Accesses	0	1	2	3	4	1	3	4	4	5	3	1	2	0	4	5	4
Optimal	-	-	-	-	0	-	-	-	-	4	-	-	-	3	2	-	-
FIFO	-	-	-	-	0	-	-	-	-	1	-	2	3	4	5	1	-
LRU	-	-	-	-	0	-	-	-	-	2	-	-	4	5	3	1	-
LFU	-	-	-	-	0	-	-	-	-	2	-	-	5	2	-	0	-
MRU	-	-	-	-	3	-	1	-	-	4	-	3	-	-	0	-	-