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CS341 - Virtual Memory Assignment

Ans 1: Assume the page size is of x bits

Given, size of virtual memory is 2^{46}

$\Rightarrow$ $\boxed{\text{no. of pages in virtual memory is } \frac{2^{46}}{2^{x}} = 2^{(46-x)}}$

Since, T1 occupies exactly one page

$\Rightarrow$ $\boxed{\text{Size of } T_1 = 2^{x} \text{ bytes}}$

$$\text{No. of entries in } T_1 = \frac{\text{Size of } T_1}{\text{Size of 1 entry}} = \frac{2^{x}}{4} = 2^{x-2}$$

$\Rightarrow$ No. of second level page tables (T_2) = no. of entries in T_1 = 2^{x-2}

$\therefore$ Total size of second level page tables (T_2)

= No. of page tables $\times$ size of each table.

$$= 2^{x-2} \times 2^{x} = \underline{\underline{2^{2x-2}}}$$

Total entries in second level page tables (T_2)

$$= \frac{\text{Total Size}}{\text{Size of 1 entry}} = \frac{2^{2x-2}}{4} = 2^{2x-4}$$

Again, No. of third level page tables (T_3) = no. of entries in T_2

$$= 2^{2x-4}$$

Now, total entries in level three page tables

$$= \frac{\text{total size of level three page tables}}{\text{size of 1 entry}}$$

$$= \frac{\text{total no. of level three page tables} \times 2^x}{4}$$

$$= 2^{2x-4} \times \frac{2^x}{4} = \underline{\underline{2^{3x-6}}}$$

We also know,

$$\left.\begin{array}{l}\text{total entries in level three} \\ \text{page tables}\end{array}\right\} = \left\{\begin{array}{l}\text{no. of pages in} \\ \text{virtual memory}\end{array}\right.$$

$$\Rightarrow \quad 2^{3x-6} = 2^{46-x}$$

$$\Rightarrow \quad 2^{4x-6} = 2^{46}$$

$$\Rightarrow \quad 2^{4x} = 2^{52}$$

$$\Rightarrow \quad 2^x = 2^{\frac{52}{4}} = 2^{13}$$

$$\Rightarrow \quad \boxed{x = 13}$$

∴ Page size is of 13 bits ⇒ Page size is 2^{13} bytes

Hence $\boxed{\text{pagesize is 8KB}}$

Ans 2: Given,

memory access time = 20ns

page fault service time = 10ms

miss ratio = $\frac{1}{10^6}$ ⇒ hit ratio = $\left(1-\frac{1}{10^6}\right)$

effective memory access time (EAT)

= (hit ratio) * (memory access time)
 + (miss ratio) * (page fault service time)

$= \left(1-\frac{1}{10^6}\right) \times 20 + \left(\frac{1}{\cancel{10^6}}\right) \times 10 \times \cancel{10^6}$

$= 20-(2\times10^{-5}) + 10$ ns $= 30-(2\times10^{-5})$ ns

≈ 30ns

∴ Effective memory access time is 30ns approximately.

To be precise it is 29.99998 ns

Ans 3: Given, physical address has 36-bit
virtual address has 32-bit
page frame size is 4KB
page table entry size is 4 bytes

Address Translation involves three-level page table,

bits 30-31	$\longrightarrow$ index into level I page table		(2 bits)
21-29	$\longrightarrow$	II	(9 bits)
12-20	$\longrightarrow$	III	(9 bits)
0-11	$\longrightarrow$ offset within the page.		(12 bits)

Now, max no. of page frames $= \dfrac{\text{Size of physical address space}}{\text{Page Size}}$

$$= \frac{2^{36}}{4 \times 2^{10}} = 2^{24}$$

$\therefore$ 24-bits are required to index the page numbers in 3rd level page table.

Now, to access second level page table entry, 9 bits are used.

$\therefore$ Size of second level page table $= \underbrace{2^9}_{\text{total no. of entries}} \times \underbrace{4}_{\text{size of one entry}}$ bytes

$\Rightarrow$ Size of second level page table is 2^{11} bytes

Hence, in a 2^{36} physical address space, we can have $\frac{2^{36}}{2^{11}}$ second level page tables $(= 2^{25})$

$\therefore$ 25-bits are required to index the second level page tables

Similarly, first level page table entry requires 9 bits to access.

$\therefore$ Size of first level page table $= 2^9 \times 4$ bytes $= 2^{11}$ bytes

$\Rightarrow$ There will be 2^{25} first level page tables in a 2^{36} physical address space. Hence, we need 25-bits for indexing

$\therefore$ The answer is 25, 25, 24 bits to address next level page table in first, second & third level page tables respectively

Ans 4 Given,

capacity = 3 page frames

initially, none of the pages are available in the memory

Reference string = 1, 2, 1, 3, 7, 4, 5, 6, 3, 1

Optimal replacement policy is used.

<u>Optimal replacement policy</u>: Replace the page which is not used in the longest dimension of time in future.

Frames

	*	1	2	1	3	7	4	5	6	3	1	
F1	X	1	1	1	1	1	1	1	1	1	1	
F2	X	X	2	2	2	7	4	5	6	6	6	
F3	X	X	X	X	3	3	3	3	3	3	3	
R	0	1	2	3	4	5	6	7	8	9	10	
		*	*		*	*	*	*	*			

→ 7 page faults

no. of references

no pages available in memory

for the next reference, 2 will be replaced. because it is not used ~~called~~ in future

for next reference, 5 is replaced because it is not used in future.

next, 7 will be replaced because it is not used in future

for next reference, 4 is replaced because it is not used in future

$\boxed{\text{Therefore, there will be 7 page faults}}$

Ans 5

Given,

TLB access time = 10ms

Memory access time = 80ms

TLB hit ratio = 0.6 ⇒ TLB miss ratio = 1 − 0.6 = 0.4

effective memory access time (EMAT)

= (TLB hit ratio) × (TLB access time + memory access time)

+ (TLB miss ratio) × (TLB access time + page table access time + memory access time)

$= 0.6 \times (10 + 80) + 0.4 \times (10 + 80 + 80)$ ms

[I assume page table lookup takes only one memory access ⇒ page table access time = 80ms]

$= 0.6 \times 90 + 0.4 \times 170$ ms

$= 54 + 68 = 122$ ms

⇒ $\boxed{\text{effective memory access time is 122 milliseconds}}$