Solution to Practice Problems on Memory Management

② offset $= \log_2(\text{page size in Bytes}) = \log_2(4 \times 1024) = 12$ bits

physical address $= \log_2(8 \times 2^{30}) = 33$ bits

$\therefore$ PFN $= 33 - 12 = 21$ bits

$\therefore$ PTE size $= \left\lceil \dfrac{21 + 10}{8} \right\rceil = 4$ Bytes

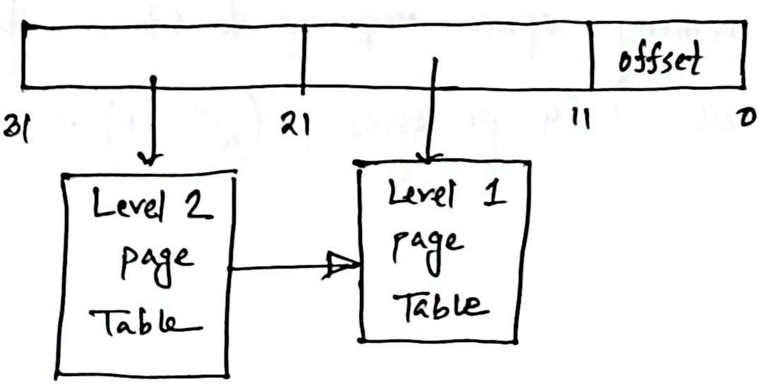
Virtual address $= \log_2(4 \times 2^{30}) = 32$ bits

$\therefore$ VPN $= 32 - 12 = 20$ bits.

Now, to ~~find~~ design the multi-level page table:–

Number of bits required at each level page table

$$= \log_2\left(\frac{\text{page size}}{\text{PTE size}}\right) = \log_2\left(\frac{4 \times 1024}{4}\right) = 10 \text{ bits.}$$



Maximum memory space required for the page tables of a $\boxed{\text{single process}}$:-

Number of pages required for each level page table $= \dfrac{\text{No. of PTEs}}{\text{No. of PTEs per page}}$ —— ①

Now, No. of PTEs per page $= \dfrac{\text{page size}}{\text{PTE size}} = \dfrac{4 \times 1024}{4}$

$= 1024$

$= 2^{10}$

$\therefore$ ① $\Rightarrow$ Memory space for level 1 $= \dfrac{2^{20}}{2^{10}} = 2^{10}$

Memory space for level 2 $= \dfrac{2^{10}}{2^{10}} = 1$

$\therefore$ Total space $= (2^{10} + 1)$ pages

$\therefore$ Maximum memory space required to store the page tables of all 1024 processes $= (2^{10} + 1) \times 1024$ pages.

Ans.

③ Given, page size = 16 byte

$\therefore$ offset = $\log_2(16) = 4$ bits

$\therefore$ VPN = $6 - 4 = 2$ bits

(a) Virtual Address = $20_{(10)} = \underbrace{01}_{\text{VPN}}\underbrace{0100}_{\text{offset}}{}_{(2)}$

$\therefore$ Corresponding PFN = $3 = 11_{(2)}$

$\therefore$ Physical address = $110100_{(2)} = 52_{(10)}$

(b) Virtual address = $40_{(10)} = \underbrace{10}_{\text{VPN}}\ \underbrace{1000}_{\text{offset}}$

$\therefore$ VPN = $10_{(2)} = 2_{(10)}$

$\therefore$ PFN = $11_{(10)} = 1011_{(2)}$

$\therefore$ Physical address = $1011\,1000_{(2)} = 184_{(10)}$

Ans.

(4) Given, 64-bit system running an OS.

$\therefore$ Virtual address = 64 bits.

page size = 4KB = 4×1024 Bytes

PTE size = 4 bytes.

(a) offset = $\log_2(4 \times 1024) = 12$ bits.

Number of bits required at each level of page table = $\log_2\left(\frac{\text{page size}}{\text{PTE size}}\right) = \log_2\left(\frac{4 \times 1024}{1024}\right)$

$= 10$ bits.

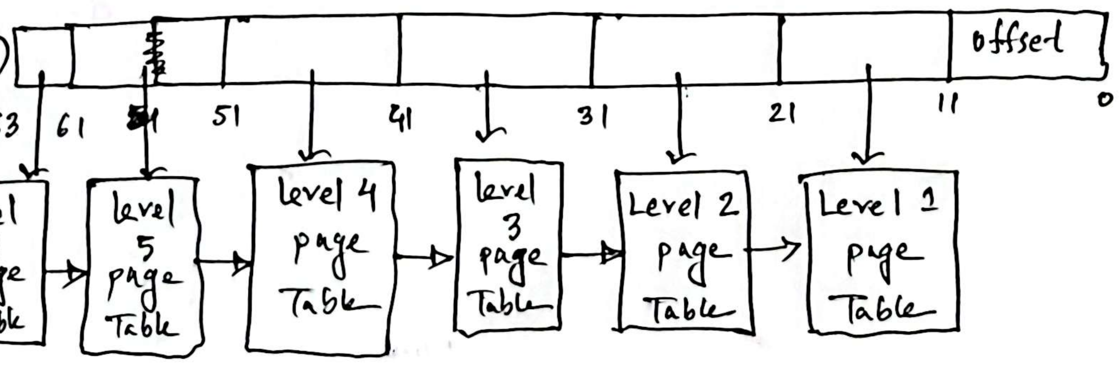
VPN = 64 − 12 = 52 bits

64 ↓ virtual address

12 ↓ offset

$\therefore$ Maximum number of levels in the page table of a process $= \left\lceil \frac{52}{10} \right\rceil = 6$ levels.

(b)



4(c) Maximum number of pages for,

level 1 $= \frac{2^{52}}{2^{10}} = 2^{42}$ pages

level 2 $= \frac{2^{42}}{2^{10}} = 2^{32}$ pages

level 3 $= \frac{2^{32}}{2^{10}} = 2^{22}$ pages

level 4 $= \frac{2^{22}}{2^{10}} = 2^{12}$ pages

level 5 $= \frac{2^{12}}{2^{10}} = 2^{2}$ pages

level 6 $= \left\lceil \frac{2^{2}}{2^{10}} \right\rceil = 1$ page

Number of PTEs per page

$= \frac{\text{page size}}{\text{PTE size}}$

$= \frac{4 \times 1024}{4}$

$= 1024$

$= 2^{10}$

$\therefore$ Total $= (2^{42} + 2^{32} + 2^{22} + 2^{12} + 2^{2} + 1)$ pages.

Ans.

(5) $\text{offset} = \log_2(4 \times 1024) = 12 \text{ bits}$

(a) Virtual Address = $\underbrace{0000\ 0000\ 0011}_{\text{VPN}}\ \underbrace{0000\ 1010\ 1111}_{\text{offset}}$

$\Downarrow$

0x 003 (Hexadecimal)

$\therefore$ PFN = 0x 32A0

$\therefore$ physical Address = $\underbrace{\boxed{0011\ 0010\ 1010\ 0000}}_{\text{PFN}}\underbrace{\boxed{0000\ 1010\ 1111}}_{\text{offset}}$

You can solve such questions in the following tabular format:

Ques no.	Virtual Address	VPN	PFN	Physical Address
(b)	0000 0000 0101 0000 0000 0101	0x 005	×	× (as valid bit is 0)
(c)	0000 0000 0111 0001 1111 0111	0x 007	0x 000AB	0000 0000 0000 1010 1011 0001 1111 0111

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