



United International University
Department of Computer Science and Engineering

OS CT 3

Full Marks: 20

Name:

ID:

Q1: A system uses byte-addressing, 13-bit virtual addresses, 1K physical frames, multi-level page tables, and pages that hold 16 page table entries. Each page table entry stores: read, write, execute, modified, and valid bits additional to PFN. Each page table entry size is rounded up to the nearest byte. Answer the following:

- (a) How many unique virtual addresses can a process generate? [1]
- (b) What is the size of a page table entry (in bytes)? [2]
- (c) What is the size of a page (in bytes)? [2]
- (d) What is the size of physical memory (RAM) (in bytes)? [2]
- (e) Define internal and external fragmentation. Which type occurs in this system? [3]
- (f) What is the least and most memory wastage (in bits) in a page table per process? [2]
- (g) What is the minimum number of processes that can run concurrently? [2]
- (h) What is the maximum number of processes that can run concurrently? [2]

Q2: Explain the worst-case virtual-to-physical address translation using CPU, TLB, RAM, and disk. Include a labeled diagram showing the complete path of translation. [4]

1(a) 2^{13} virtual addresses

(b) PFN size = $\log_2(1024) = 10 \text{ bits}$ [1K = 1024]

Flags = 5 bits

\therefore PTE size = $10 + 5 = 15 \text{ bits} \approx 2 \text{ Bytes}$

↳ (1 bit is wasted per PTE)

(c) PTEs per page = 16

PTE size = 2 Bytes

Internal fragmentation

\therefore Page size = $16 \times 2 = 32 \text{ Bytes}$

(d) RAM size = $1024 \times 32 = 2^{15} \text{ Bytes} = 32 \text{ KB}$

(e) Here, internal fragmentation occurs.

Maximum memory wastage in page table per process

$$= (\text{page size} - \text{PTE size}) \times \text{no. of levels pages}$$

$$= (32 \times 8 \text{ bits} - 15 \text{ bits}) \times (2^4 + 1) \quad [\text{From previous page}]$$

$$= 4097 \text{ bits}$$

Ans.

level 1

level 2

Maximum memory wastage in page table per process

$$= \text{wastage in level 1} + \text{wastage in level 2}$$

(each page has only 1 entry)

(This page has entries equal to num of pages in level 1)

$$= (32 \times 8 - 15) \times 2^4 \text{ bits} + (32 \times 8 - 15 \times 2^4) \text{ bits}$$

$$= 3856 \text{ bits} + 16 \text{ bits}$$

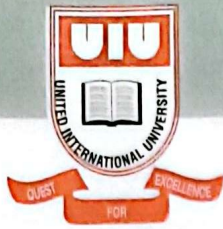
$$= 3872 \text{ bits.}$$

(3) Min^m Num. of processes that can run concurrently

$$= \frac{\text{RAM size}}{\text{Max Memory (virtual + page table) for a process}}$$

$$\therefore \text{Min}^m \text{ number} = \frac{32 \text{ KB}}{\underbrace{2^{13} \text{ Bytes}}_{\text{Max virtual memory}} + \underbrace{(2^4 + 1) \times 32 \text{ Bytes}}_{\text{Max page table space}}} = \left\lfloor \frac{32 \times 2^{10}}{8736} \right\rfloor \approx 3$$

Ans.



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Name of Exam: Class Test / Mid-term / Mid-term (Makeup/Improvement) / Final / Final (Makeup/Improvement)

(h) Max^m numbers of processes that can run concurrently

$$= \frac{\text{RAM Size}}{\text{Minimum Memory (virtual + page table) for a process}}$$

$$= \frac{32 \text{ KB}}{32 \text{ B (1 page)} + (32 \text{ B} \times 2) \text{ (2 page for table)}}$$

$$= \left\lceil \frac{32 \times 2^{10}}{96} \right\rceil$$

$$= 341 \text{ processes}$$

Ans.

(f) least memory wastage in a page table

= 1 page with 16 entries from level 1 +
1 page with 1 entry

$$= 16 \times 1 \text{ bit} + \underbrace{(32 \times 8)}_{\text{page size}} - \underbrace{15}_{\substack{\downarrow \\ \text{1 PTE size}}} \text{ bits}$$

$$= 257 \text{ bits.}$$

An.