



United International University
Department of Computer Science and Engineering

OS CT 3

Name:

Full Marks: 20

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 = $\log_2(1024) = 10$ bits [$1K = 1024$]

Flags = 5 bits

\therefore PTE size = $10 + 5 = 15$ bits ≈ 2 Bytes

(c) PTEs per page = 16

PTE size = 2 Bytes

\therefore Page size = $16 \times 2 = 32$ Bytes

↳ (1 bit is wasted per PTE)

Internal fragmentation

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

(e) Hence, internal fragmentation occurs.

Maximum memory wastage in page table per process

$$= (\text{page size} - \text{PTE size}) \times \cancel{\# \text{ of } \cancel{\text{levels}}} \text{ pages}$$

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

~~4096~~ bits
4097 An.

↓
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 2)

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

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

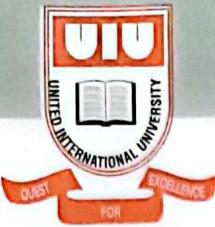
$$= 3872 \text{ bits.}$$

(Q) Min Num. of processes that can run concurrently

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

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

Max page table space



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Section

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Trimester / Semester: Spring / Summer / Fall, 20.....

Date:

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

(a) Max^m number of processes that can run concurrently

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

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

$$= \left[\frac{32 \times 2^{10}}{96} \right]$$

$$= 341 \text{ processes}$$

Ans.

(f) least memory wastage in a page table

= 1 page with 16 entries from level 1 +

1 page with 1 entry

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

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

An.