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

Flags $= 5$ bits

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

$\rightarrow$ (1 bit is wasted per PTE) $\underbrace{}_{\text{Internal fragmentation}}$

(c) PTEs per page $= 16$

PTE size $= 2$ Bytes

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

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

(e) Here, internal fragmentation occurs.

Maximum memory wastage in page table per process

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

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

$= \cancel{4082}$ bits
4097 Ans..

Maximum memory wastage in page table per process

= wastage in level 1 + wastage in level 2

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

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

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

$= 3872 \text{ bits}.$

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

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

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

Ans

United International University

Name (Optional)

ID No. Section

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Course Code

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

Date: ....

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

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

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

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

$$= \left\lfloor \frac{32 \times 2^{10}}{96} \right\rfloor$$

$= 341$ processes

Ans.

(f) <u>least memory wastage in a page table</u>

= 1 page with 16 entries from level 1 +

1 page with 1 entry

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

= 257 bits.

An.