Grade 12 A/L ICT · Lesson 5

5.4 Memory Management, Paging, Device Drivers and Spooling

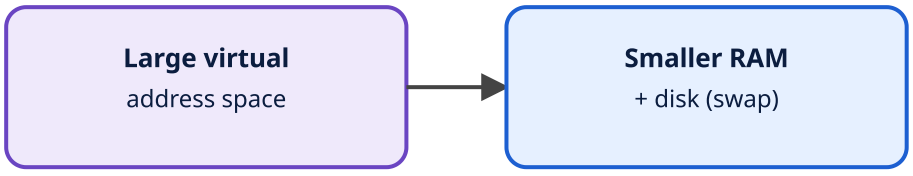
Syllabus 5.4. The OS manages **memory** with help from the **MMU**, supports **virtual memory** and **paging**, and controls **I/O devices** through **device drivers**. **Spooling** queues output (for example to a printer). In this part you practise **address calculations**: page number, offset and physical address.

1. Why manage memory?

Many programs share limited RAM. The OS must **allocate**, **protect** and **map** memory so each process sees a private address space and cannot overwrite another. The **Memory Management Unit (MMU)** is hardware that translates addresses and checks permissions.

2. Virtual memory and paging

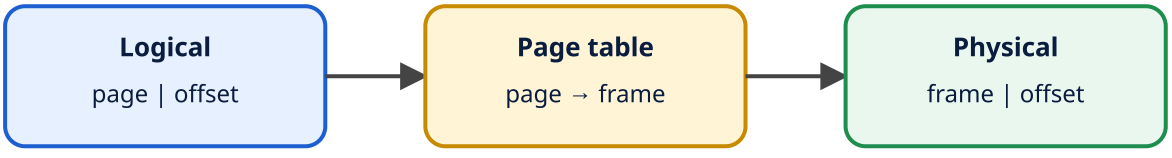
Virtual memory idea



Virtual memory idea

Virtual memory lets a process use a large logical address space. Parts that do not fit in RAM live on disk (swap/page file). **Paging** splits memory into fixed-size **pages** (logical) and **frames** (physical). A **page table** maps page → frame.

Logical address → physical address



Logical address to physical address

Logical address = **page number** × page size + **offset**. Physical address = **frame number** × page size + **offset** (same offset).

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🧱 **Worked example: Page size = 1024 bytes (1 KB). Logical address 3500. Find page number and offset.**
page = 3500 ÷ 1024 = **3**; offset = 3500 mod 1024 = **428**.

🧱 **Worked example: If page 3 is loaded in frame 5, what is the physical address?**
PA = 5 × 1024 + 428 = **5548**.

🧱 **Worked example: A process needs 10 KB. Page size = 1 KB. How many pages?**
10240 ÷ 1024 = **10 pages**.

🧱 **Worked example: A system uses 16-bit logical addresses and a 1024-byte page. How many bits are the offset and the page number? How many pages can a process address?**
Offset bits = $\log_2(1024)$ = **10**; page bits = 16 − 10 = **6**; max pages = 2^6 = **64**.

💡 **Mapping** means translating logical → physical using the page table (and MMU cache / TLB in real machines).

3. I/O device management

Keyboards, disks, printers and USB devices differ. The OS talks to them through **device drivers** – software modules that hide hardware details and present a uniform interface (read, write, control).

- **Need for drivers:** each device has its own registers and protocols.
- When you plug in a printer or USB stick, the OS loads the matching driver (or asks you to install one).
- Without the right driver the device is invisible or limited.

4. Spooling

Spooling (Simultaneous Peripheral Operations On-Line) stores data destined for a slow device (classically a printer) on disk first, then feeds the device in the background. Many users can "print" at once without waiting for the paper.

🧱 **Worked example: Why is a print spooler useful in a school computer lab?**
Many students send jobs; the spooler queues them on disk so each PC can continue working while the shared printer prints one job after another.

🚀 **Beyond the syllabus (2026 update)** *Not required for the exam – read for interest.* In 2026, phones use zRAM and sophisticated paging; laptops mix SSD swap with large RAM. GPU drivers and USB-C dock drivers are still the usual reason a new peripheral "does not work until you install software". Cloud print queues are spooling in another building.

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Key Words

MMU – Memory Management Unit – hardware address translation and protection.

Physical memory – The real RAM chips and their addresses.

Virtual memory – Large logical space backed by RAM + disk.

Paging – Fixed-size pages mapped to frames.

Page – Fixed-size block of a process's logical address space.

Frame – Fixed-size block of physical RAM.

Page table – Maps page numbers to frame numbers.

Offset – Displacement within a page/frame.

Device driver – Software that controls a specific device for the OS.

Spooling – Queueing device I/O (e.g. print jobs) on disk.

Mapping – Translating logical addresses to physical addresses.

Swap / page file – Disk space holding pages that do not fit in RAM.

Sample Q&A

1. What does the MMU do?

> **Answer:** Translates virtual/logical addresses to physical addresses and helps enforce memory protection.

2. What is virtual memory?

> **Answer:** A technique that gives processes a large logical address space using RAM plus disk backing store.

3. Define page and frame.

> **Answer:** A page is a fixed-size logical block; a frame is a same-size block of physical RAM.

4. Why are device drivers needed?

> **Answer:** Each device has different hardware details; drivers hide them so the OS can use a common interface.

5. What is spooling?

> **Answer:** Storing output (e.g. print jobs) on disk and sending it to a slow device later/in the background.

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6. For LA=3500 and page size 1024, what are page and offset?

> **Answer:** Page 3, offset 428.

MCQ

1. The MMU mainly

A. prints pages
B. stores passwords only
C. translates addresses and helps protect memory
D. formats USB only
E. draws desktop icons

2. Virtual memory allows

A. processes to use more logical space than physical RAM
B. only one file on disk
C. turning off the MMU forever
D. removing the CPU
E. no address translation

3. In paging, a frame is

A. a keyboard key
B. an IP address
C. a user password
D. a GUI window only
E. a fixed-size block of physical memory

4. Logical address =

A. frame only
B. page number × page size + offset
C. file name length
D. MAC address
E. CPU temperature

5. For LA 3500 and 1 KB pages, the page number is

A. 3500
B. 10
C. 3
D. 0
E. 1024

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6. With page 3 in frame 5 and offset 428, PA is

A. 3500
B. 0
C. 5
D. 5548
E. 1024

7. A 10 KB process with 1 KB pages needs

A. 100 pages
B. 1 page
C. 1024 pages
D. 10 pages
E. 0 pages

8. A device driver is

A. a power cable only
B. software that lets the OS control a device
C. a font file
D. a type of RAM chip
E. a desk chair

9. Spooling is often used for

A. CPU register renaming only
B. screen brightness only
C. cooling fans only
D. BIOS flashing only
E. print jobs queued on disk

10. Offset bits for a 1024-byte page are

A. 10
B. 8
C. 16
D. 64
E. 1

11. With 16-bit logical addresses and 10 offset bits, page bits =

A. 32
B. 6
C. 0
D. 10
E. 16

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12. Mapping in this lesson means

A. changing wallpapers
B. drawing a geography map
C. logical → physical address translation
D. sorting files by colour
E. deleting drivers

13. Which term means: “Memory Management Unit – hardware address translation and protection”?

A. Mapping
B. Virtual memory
C. Frame
D. Offset
E. MMU

14. Which term means: “The real RAM chips and their addresses”?

A. Physical memory
B. Paging
C. Device driver
D. Page table
E. Swap / page file

15. Which term means: “Large logical space backed by RAM + disk”?

A. MMU
B. Spooling
C. Offset
D. Virtual memory
E. Page

16. Which term means: “Fixed-size pages mapped to frames”?

A. Mapping
B. Frame
C. Device driver
D. Paging
E. Physical memory

17. Which term means: “Fixed-size block of a process’s logical address space”?

A. Page table
B. Virtual memory
C. Spooling
D. Swap / page file
E. Page

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18. Which term means: “Fixed-size block of physical RAM”?

A. Mapping
B. Frame
C. Offset
D. MMU
E. Paging

19. Which term means: “Maps page numbers to frame numbers”?

A. Swap / page file
B. Device driver
C. Page table
D. Physical memory
E. Page

20. Which term means: “Displacement within a page/frame”?

A. Offset
B. MMU
C. Virtual memory
D. Frame
E. Spooling

Structured Questions

1. Explain why memory management and the MMU are needed. *(2 marks)*

> Share limited RAM safely (1); MMU translates and protects (2).

2. Describe virtual memory and paging in three clear points. *(3 marks)*

> Large logical space (1); pages/frames (1); page table maps (1).

3. For LA=3500, page size 1 KB, frame 5: find page, offset, PA. *(3 marks)*

> Page 3 (1); offset 428 (1); PA 5548 (1).

4. Explain device drivers and why installing them matters. *(3 marks)*

> Software interface to hardware (1); without driver device limited/unusable (1); example printer/USB (1).

5. Define spooling and give a school-lab printer example. *(3 marks)*

> Queue output on disk (1); printer prints in background (1); many students share one printer (1).

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Summary

- The MMU translates and protects memory addresses.
- Virtual memory + paging map pages to frames via a page table.
- Logical address = page × size + offset; physical uses frame × size + offset.
- Device drivers let the OS control varied hardware.
- Spooling queues slow-device output (e.g. printing) on disk.

MCQ answer key – 5.4

1. **C** – Address translation hardware.
2. **A** – RAM + disk backing.
3. **E** – Physical page-sized block.
4. **B** – Page and offset.
5. **C** – 3500//1024=3.
6. **D** – 5*1024+428.
7. **D** – 10.
8. **B** – Per-device software.
9. **E** – Classic printer spool.
10. **A** – log2(1024)=10.
11. **B** – 16−10=6.
12. **C** – Page-table translation.
13. **E** – MMU – Memory Management Unit – hardware address translation and protection.
14. **A** – Physical memory – The real RAM chips and their addresses.
15. **D** – Virtual memory – Large logical space backed by RAM + disk.
16. **D** – Paging – Fixed-size pages mapped to frames.
17. **E** – Page – Fixed-size block of a process’s logical address space.
18. **B** – Frame – Fixed-size block of physical RAM.
19. **C** – Page table – Maps page numbers to frame numbers.
20. **A** – Offset – Displacement within a page/frame.

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