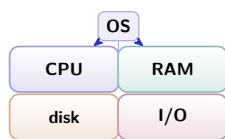


System Software

A-Level Computer Science • Topic 16

A-Level Computer Science



System Software

What we will cover

- 1 How an OS shares resources
- 2 Processes, scheduling, memory
- 3 Interpreters and compilers
- 4 BNF, syntax diagrams, RPN
- 5 Recap

1 Sharing resources

System Software
└─ Sharing resources

The OS shares four scarce things

Many programs compete for CPU time, memory, disk and I/O. The OS shares them fairly so the machine stays responsive.

multi-tasking 多任务

switch the CPU quickly so several programs *seem* to run at once

paging 分页

give each process memory; use disk when RAM runs out

spooling 假脱机

queue print jobs on disk so the CPU never waits

caching 高速缓存

keep recently-used disk data in RAM

System Software
└─ Sharing resources

The user interface hides the hardware

The user sees windows, menus and folders – not addresses or sectors. One click on an icon makes the OS find the program, allocate memory, load it and start it.

CLI

powerful, scriptable

GUI

easier to learn

Most systems offer both. The interface is an abstraction, not a different OS.

2 Processes

A process is a program in execution

Its code, current state, memory and open files. The **scheduler** 调度器 chooses which **ready** process runs next, and for how long.

round robin

each process gets a fixed **time slice** 时间片, then the back of the queue

FCFS

first-come, first-served – simple, can stall behind a long job

SJF / SRT

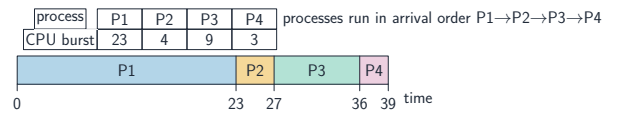
shortest job, or shortest remaining time

priority

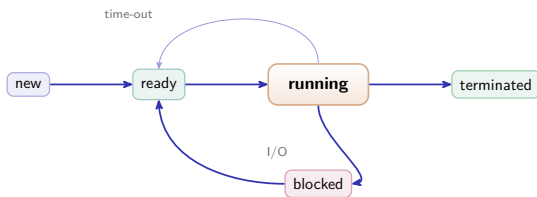
urgent work first; risk of starvation

First come, first served

Simple and fair in arrival order, but one long job delays everything behind it.



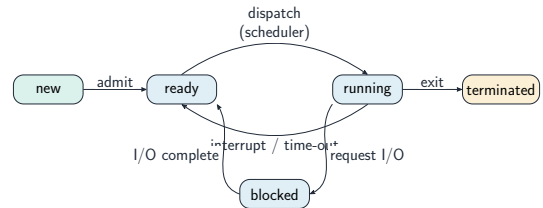
Process states



Time slice ends: running → ready. I/O requested: running → blocked. I/O done: blocked → ready.

The state diagram

Ready, running, blocked – and only the scheduler moves a process between ready and running.



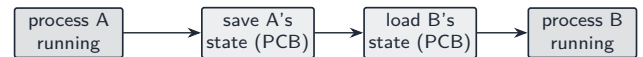
PCB and context switch

For each process the OS keeps a **process control block** 进程控制块 (PCB): saved program counter, registers, state, memory info. A **context switch** 上下文切换 saves one PCB and loads another. A small cost, paid on every switch.

Isolated processes talk via **IPC** 进程间通信: **pipes** 管道, **shared memory** 共享内存, message passing.

The **kernel** 内核 is the interrupt handler: a device or the timer raises an interrupt, the running process is saved, and the right routine runs.

Process control block and context switch

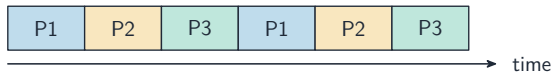


A context switch saves one process's state and loads another's

Round robin

Each process gets a fixed **time slice** 时间片; when it expires the scheduler switches to the next.

each process gets a fixed time slice, then the next one runs



Virtual memory, paging, thrashing

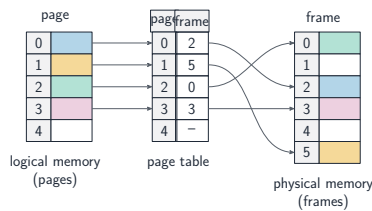
Each process gets its own **virtual address space** 虚拟地址空间, mapped onto physical memory.

- **pages** 页 ↔ **frames** 页框 of the same size
- a page table stores the mapping
- a **page fault** 缺页 loads the page from the **swap file** 交换文件

Thrashing 抖动 is when the OS spends most of its time swapping pages instead of running programs – too little RAM for the working set.

Segmentation 分段 splits memory into variable-sized logical chunks (code, stack, heap), each with its own permissions.

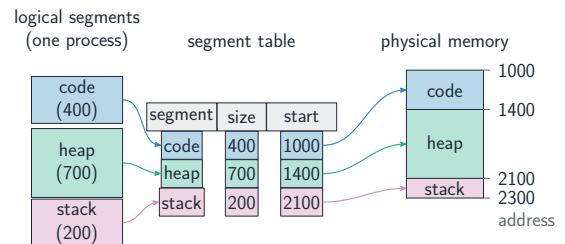
Virtual memory, paging, segmentation



Paging maps each page of logical memory to a frame of physical memory

Paging and segmentation

Paging splits memory into equal **pages** 页; segmentation splits it into logical, unequal **segments** 段.



3 Translation

How an interpreter runs a program

An **interpreter** 解释器 translates and runs the source at the same time.



- errors are reported immediately; it usually stops
- no executable is produced – translation is redone every run
- slower, but fast development feedback and portable

System Software
└ Translation

Two more jobs the OS does, and how a compiler reads code

Interrupt handling

Interrupt handling 中断处理: a device raises a signal, the CPU saves state, runs the handler, and resumes – so no polling loop is needed.

Inter-process communication

Inter-process communication 进程间通信: pipes, shared memory and message queues let separate processes exchange data under the OS's control.

Lexical analysis

Lexical analysis 词法分析 splits the source into tokens and strips comments and whitespace.

Syntax analysis

Syntax analysis (parsing) 语法分析 builds an abstract syntax tree 抽象语法树 from those tokens – and reports a syntax error 语法错误 when they fit no rule.

Then

Code optimisation 代码优化 improves the intermediate form, and code generation emits machine code or bytecode 字节码.

A syntax error is caught before anything runs; a logic error is not caught at all. The compiler can only check the grammar.

System Software
└ Translation

Five stages of compilation

A compiler 编译器 turns source into machine code 机器码.

1
lexical

groups characters into tokens 词法单元

2
syntax

check the grammar; build an AST

3
semantic

does it make sense? types, declarations

4
codegen

emit target code, choose registers

5
optimise

fold constants, remove dead work

System Software
└ Translation

Five stages of compilation, in detail

source code

lexical (tokens)

syntax (AST)

semantic (checks)

code generation

optimise

executable

The phases of compilation, from source code to an optimised executable

System Software
└ Translation

Syntax, as a diagram

A syntax diagram says the same as BNF: follow any path through it and you get a valid construct.

assignment:

identifier

:=

expression

rectangle = non-terminal rounded = terminal

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Grammar and RPN

System Software
└ Grammar and RPN

BNF – a grammar in text

Backus-Naur Form 巴科斯-诺尔范式 writes a grammar 文法 as production rules: <digit> ::= 0 | 1 | ... | 9

<identifier> ::= <letter> | <identifier> <letter> | <identifier> <digit> < > are non-terminals 非终结符; literals are terminals 终结符. Recursion expresses “any number of”.

A syntax diagram 语法图 (railroad diagram) shows the same grammar graphically. The parser uses either to decide whether a program is valid.

Reverse Polish Notation needs no brackets

Infix: operator between operands, so you need brackets and precedence.
RPN 逆波兰表示法 (postfix): operator *follows* its operands.



Scan left to right with an operator **stack** 栈: output operands; pop higher-or-equal precedence operators before pushing; parentheses flush the stack.

Worked example – evaluate RPN

Evaluate 3 4 2 * +

Push each operand; on an operator, pop two, apply, push the result.

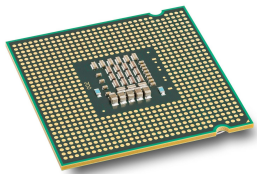
Token	Stack
3	3
4	3, 4
2	3, 4, 2
*	3, 8
+	11

$(A + B) \times (C - D)$

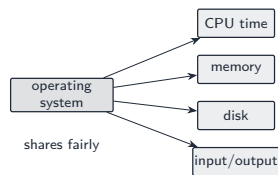
Convert: A B + C D - ×

Evaluate $(3 + 4) \times (5 - 2)$: push 3, 4; + → 7; push 5, 2; - → 3; × → **21**.

How an OS maximises use of resources



The processor is a key resource the OS shares between competing tasks



The OS shares the CPU, memory, disk and I/O between programs

The processor is a key resource the OS shares between competing tasks

What a scheduler is trading off

responsiveness	how quickly an interactive process gets a turn
throughput	how many processes complete per unit time
fairness	every process getting a share, and none starving
the trade-off	you cannot maximise all three – and each algorithm picks a different corner
first come, first served	maximum fairness by arrival, and terrible responsiveness behind a long job
round robin	good responsiveness; a short time slice costs throughput in context switching

Naming the trade-off is what turns a list of algorithms into an answer. Say which of the three a given algorithm sacrifices.

The OS also manages memory (RAM)



The OS also manages memory (RAM), deciding what to keep in it and what to page out to disk

Exam tips

- List the **stages of compilation** (lexical, syntax and semantic analysis, code generation, optimisation) and what each does.
- Explain **virtual memory and paging** (disk used as extra RAM) and its cost (disk thrashing).
- Evaluate **Reverse Polish Notation** with a stack – no brackets are needed.
- Use **BNF** or a **syntax diagram** to test whether a string is valid.

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Recap

System Software
└─Recap

Topic 16 – key takeaways

1 OS

multi-task, page, spool, cache;
PCB / context switch

2 Memory

virtual addresses, pages, faults,
thrashing

3 Compile

lex, parse, semantic, generate,
optimise

4 RPN

postfix; evaluate with an
operand stack

System Software
└─Recap

Check yourself

- 1 Round-robin: what happens when a time slice ends?
- 2 What is thrashing?
- 3 Name the five compilation stages in order.
- 4 Evaluate $5 \ 1 \ 2 \ + \ 4 \ \times \ +$

Answers 1. it goes to the back of the ready queue 2. constant paging, little useful work 3. lex, syntax, semantic, codegen, optimise 4. $5 + (1 + 2) \times 4 = 17$