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Computer Architecture 2023-24 (WBCS010-05)

Lecture 1: Introduction

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Topics

- What is the Computer Architecture course about?
  - What does a computer do?
  - How does a computer work?
  - What is a computer system?
  - What are the main components of a computer system?
- What will you learn?
  - The hardware of a computer
  - The relationships with other courses

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Topics

- Course details
  - Lectures
  - Tutor sessions
  - Lab sessions
  - Assignments
  - Final exam
  - Evaluation

What does a Computer do?

- A computer is a complex electronic device that processes data according to a set of instructions called a program.

- Computers are versatile devices capable of
  - processing,
  - storing,
  - and communicating
- information.

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How does a Computer Work?

- There is **no magic** to computing!
  - Deterministic system – behaves the same way every time
  - Does exactly what we **tell** it to do: no more, no less
  - Complex system made of very simple parts
  - Even recent advances in AI come from our ability to do many (billions!) simple computations very fast!

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A Computer Program

- A computer program is a set of instructions that tells a computer how to perform a specific task or series of tasks.

- These instructions are written in a programming language that a computer can understand and execute.

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What do Computers Understand?

- Computers "understand" information in a highly structured and binary way.
- At their most fundamental level, computers work with binary code, which consists of sequences of **0**s and **1**s.
- Computers have their own language. The programs should be translated into their language.

How to Execute a Program?

- A program is a sequence of instructions.
- The questions arise are:
  - Where to put the program to execute?
  - Where to execute each instruction?
  - In what order are the instruction executed?
  - How to receive user input?
  - How to communicate the result of execution?

- We need a few components that can interact with each other.

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What is a Computer System?

- A computer system is a nominally complete computer that includes
  - the hardware,
  - operating system (main software),
  - and peripheral equipment needed and used for full operation.

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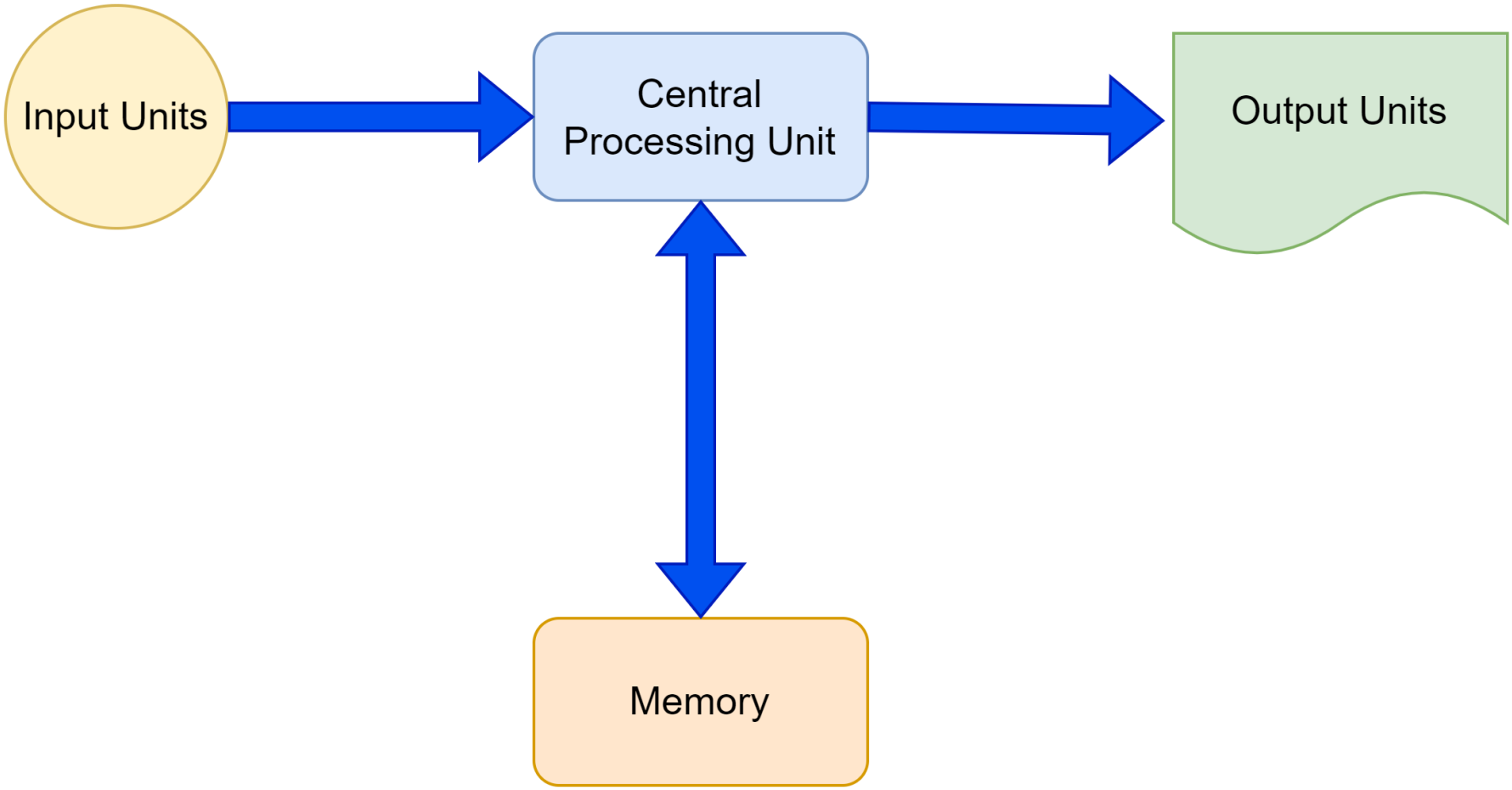
Block Diagram of a Computer



Central Processing Unit (CPU)

- In responsible for executing instructions.

- Controls and oversees the execution of instructions, manages data flow, controls input/output operations, and ensuring proper synchronization of the various components.

Memory

- Is used to store programs and data.
- Enables the computer to store and retrieve information efficiently.

Input/Output Units

- Input units allow users to input data and commands
- They facilitate the interaction between users and the computer by converting various forms of input into a format that the computer can understand and process.
- Output units are devices that present information processed by the computer to the user in a human-readable format.

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What about Operating Systems?

- The operating system (OS) is a crucial software component that serves as an intermediary between the computer hardware and the user or applications.

- It plays a fundamental role in managing and controlling the computer system.

Brief History of Computers (I)

- 1st Generation:
  - from 1940 to 1955.
  - machine language was developed.
  - vacuum tubes were used for the circuitry.
  - magnetic drums were used as memory.
  - these computers were large, and expensive, using batch operating systems and punch cards.
  - magnetic tape and paper tape were implemented.
  - examples, ENIAC, UNIVAC-1, EDVAC.

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Brief History of Computers (II)

- 2nd Generation:
  - from 1957-1963
  - COBOL and FORTRAN were employed as programming languages.
  - hardware advanced from vacuum tubes to transistors.
  - computers became smaller, faster and more energy-efficient.
  - examples, IBM 1620, IBM 7094, CDC 1604, CDC 3600.

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Brief History of Computers (III)

- 3rd Generation:
  - from 1964-1971.
  - integrated circuits(IC) were developed.
  - more computing power while lower cost.
  - computers were faster, smaller, and less expensive.
  - high-level programming languages such as PL/1, C, and PASCAL were used.
  - examples, the IBM-360 series, the Honeywell-6000 series, and the IBM-370/168.

Brief History of Computers (IV)

- 4th Generation:
  - 1971-1980
  - invention of the microprocessors.
  - C++ and Java were the programming languages used.
  - examples STAR 1000, PDP 11, CRAY-1, IBM PC, Apple Macintosh.

Brief History of Computers (V)

- 5th Generation:
  - since 1980.
  - advances in parallel processing, artificial intelligence, and supercomputing.
  - miniaturization with developments like laptops, tablets, and smartphones.

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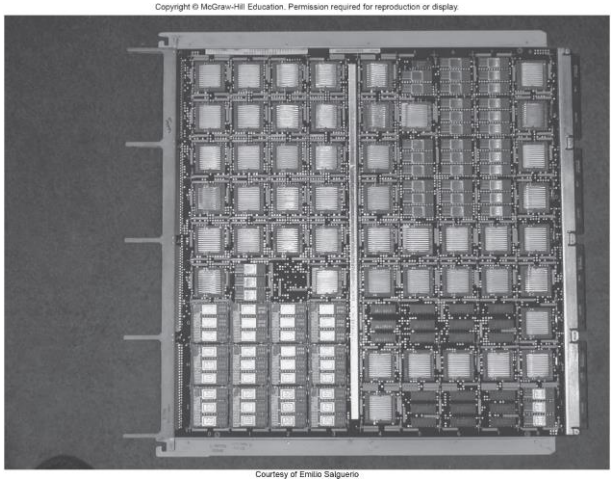
Computers from 1940s to 2010s

1940s
ENIAC
17,000 vacuum tubes 300 sq feet (8 ft tall) 30 tons 140 Kilowatts
1980s
Burroughs A Series
Dozens of IC boards 60 sq feet 1 ton 25 Kilowatts
2020s
Smartphone
1 board – system-on-chip 20 sq inches 6-8 ounces Battery-powered



› Smartphone has 4,000,000x more computing power than ENIAC

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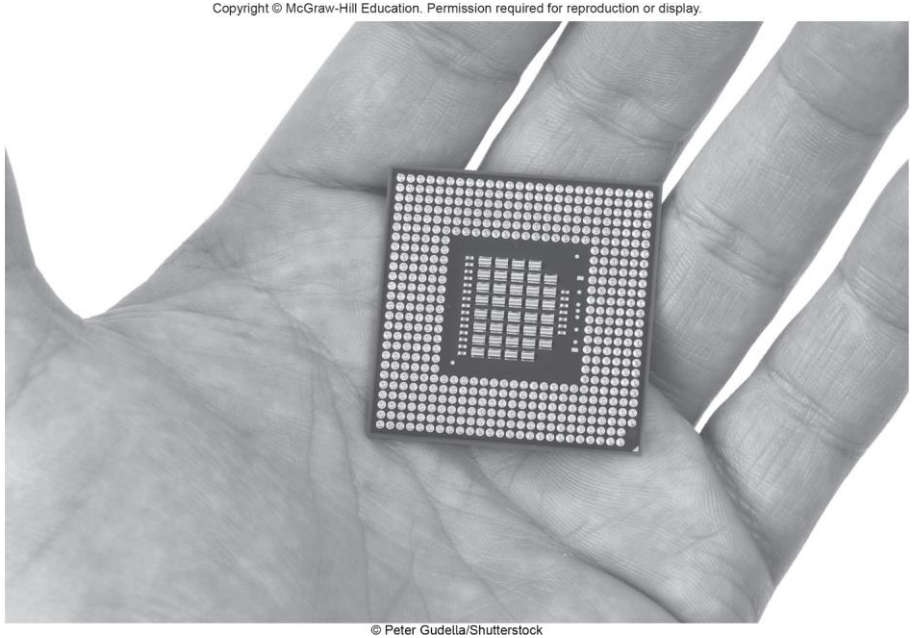
Microprocessors

1971
Intel 4004
2,300 transistors 106 kHz

1992
Intel Pentium
3.1 million transistors 66 MHz

2018
Intel Core i9
7 billion transistors 5 GHz



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- This is the processor or
- CPU (central processing unit)
- of the computer system –
  where most computation takes place

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Using Computer Systems

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What Can Computers Do?

- **All computers**, given enough time and memory, are capable of computing exactly the same things
  - Smartphone, laptop, supercomputer… limited only by time and memory
- If you can describe something in terms of computation, it can be done by a computer… again, given enough time and memory
- Important to understand how each component works, but thinking at higher levels is more efficient.

Problem Solving using Computers

- Describe the requirements of the problem
  - We want to use sensors to detect objects and guide a robot towards them ..
- Design a solution
  - Choose the algorithms, data structures, etc.
- Write the program in high level language
- Translate the program into machine language
- Load the instructions into the memory
- Execute each instruction by bringing them into the central processing unit (CPU) one-by-one
- Use input/output devices to communicate information

Abstraction

- Abstraction: Productivity Enhancer
- You don't need to worry about the details…
  - You can drive a car without knowing how an internal combustion engine works.
- Important to understand the components and how they work together.
  But thinking at higher levels of abstraction is more efficient.
- Hardware **and** Software
  - It's not either/or – both are essential components of a computer system.
  - Even if you specialize in one, you must understand the capabilities and limitations of the other.

How do We Represent Data in a Computer?

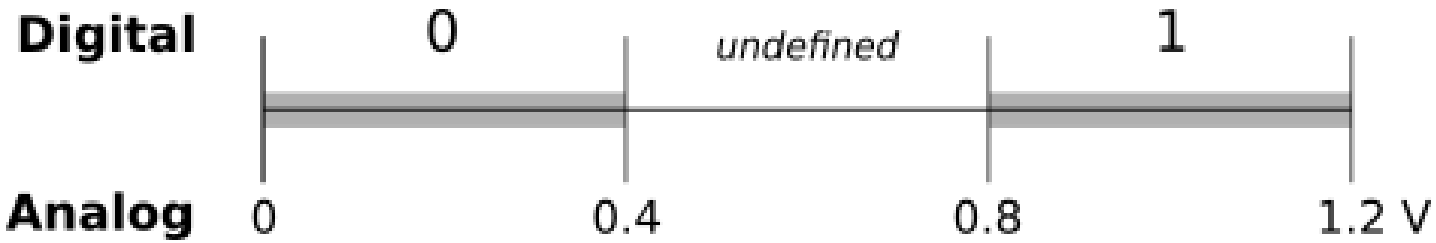
- At the lowest level, a computer is an electronic machine
  - Works by controlling the flow of electrons
- Easy to recognize two conditions:

1. Presence of a voltage – we'll call this state "1"
2. Absence of a voltage – we'll call this state "0"

- We could base the state on the value of the voltage, but control and detection circuits are more complex

Computer is a Binary Digital system

- Digital = finite number of values (compared to "analog" = infinite values)
  Binary = only two values: 0 and 1
- Unit of information = binary digit, or "bit"



- Circuits (see Chapter 3) will pull voltage down towards zero, or will pull up towards the highest voltage
- Grey areas represent noise margin -- allowable deviation due to resistance, capacitance, interference from other circuits, temperature, etc. More reliable than analog.

More Than Two Values…

- Each "wire" in a logic circuit represents **one bit** = 0 or 1
- Values with more than two states require multiple wires (bits)

- With two bits, can represent four different values:
- 00, 01, 10, 11
- With three bits, can represent eight different values:
- 000, 001, 010, 011, 100, 101, 110, 111

- With **n** bits, can represent $\mathbf{2^n}$ different values

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What Kinds of Values do We Want to Represent?

- **Numbers** - integer, fraction, real, complex, …
- **Text** - characters, strings…
- **Images** - pixels, colors, shapes…
- **Sound**
- **Video**
- **Logical** - true, false
- **Instructions**

- All data is represented as a collection of bits
- We encode a value by assigning a bit pattern to represent that value
- We perform operations (transformations) on bits, and we interpret the results according to how the data is encoded

Questions

- How are programs and data stored in memory?
- How are the instructions defined?
- How does the computer interpret instruction?
- How are data and programs displaced in a computer system?
- How is the user input received, and how are the outputs delivered?
- How do different components of a computer system work in harmony?

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Learning Outcomes

- 1) Describe the main concepts, design techniques, issues, and solutions across the abstraction layers of modern computer architectures;
- 2) Apply the acquired knowledge to programming with assembly language, including register operations, control structures, bitwise operations, and subprograms;
- 3) Describe the basic concepts of hierarchical data storage and the techniques to store and retrieve data.

Relationships with Other Courses

- As a practical matter: knowledge of computer architecture is needed for later courses, such as systems programming, compilers, operating systems, and embedded systems

- The most successful software engineers understand the underlying hardware

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Questions?

Organizational Issues

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Course structure (2023-2024)

- **Sixteen** (16) **lectures**
  - Roughly following Chapters 1 to 10 in the book,
  - Some additional information not covered in the book
  - Final review and Q&A lecture on Wednesday, January 17, 2024
- **Seven** (7) **tutorials**
  - Every Wednesday 15:00-17:00
  - For receiving guidance by the TAs
- **Seven** (7) **lab sessions** (Thursday)
  - For receiving feedback from the TAs
- **Seven** (7) **graded homework assignments**
- Slides on Brightspace
  - New relevant material will be added when necessary

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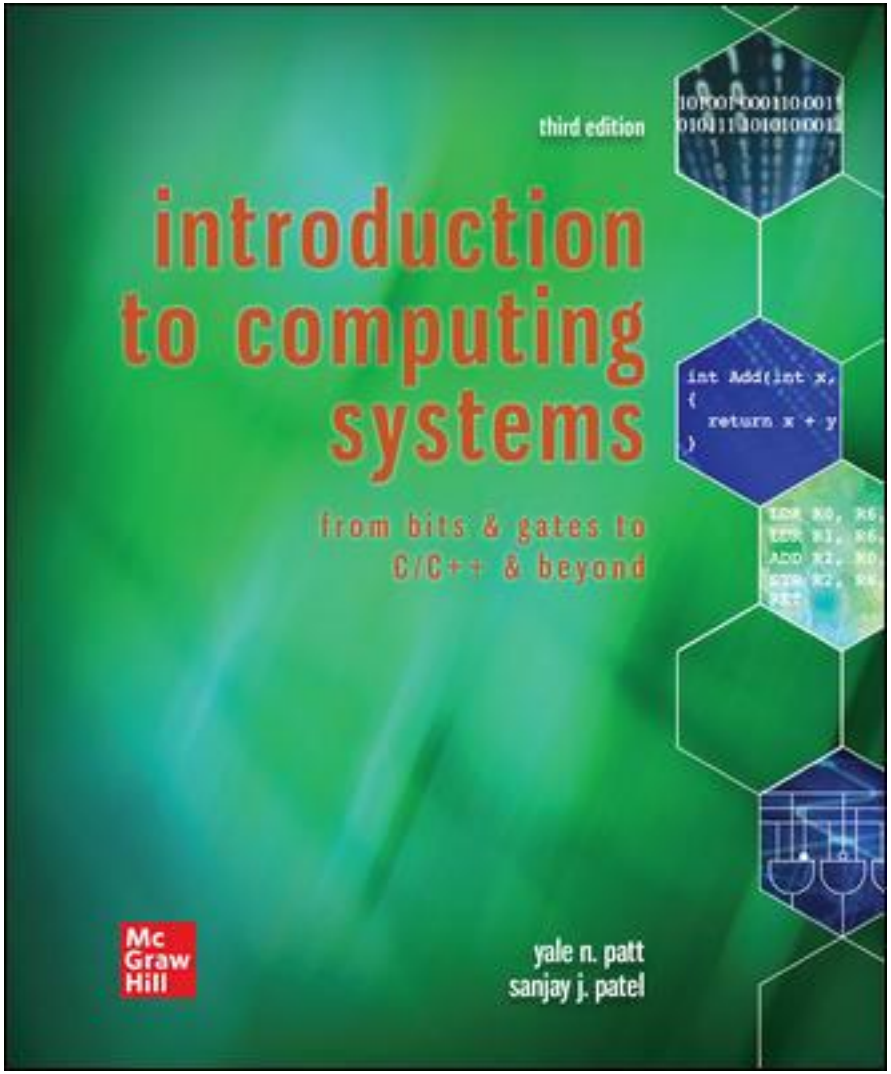
The Book (the 3rd edition)



https://www.mheducation.com/highered/product/introduction-computing-systems-bits-gates-c-c-beyond-patt-patel/M9781260150537.html

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Grading

- Final exam and/or resit, and graded practical solutions for seven (7) homework assignments

- Final grade **F=(0.4 H+0.6 E)** with
  - **H** = grade Homework **(0.125(H1..H6)+0.25H7)**
  - **E** = grade Exam/resit
  - **iff H and E >= 5.0**
- Otherwise if (**H<5 or E<5**) **F=min(H, E)**
  - 6.0 still the minimum for passing grade
  - Rounding **F** to the .5 up except for **[5.5, 6) ➔ 6**

Assignments

- Goal: to gain understanding of the computing technology internal organization, operation and the main mechanisms
- Seven (7) practical assignments
  - Content, information and deadlines **on Brightspace**
- You will work **individually**
- **Support:**
  - join the lab sessions and ask questions; or
  - send mail to **your TA**

Assignments schedule

- Seven (7) practical assignments
  - Content, information and deadlines **on Brightspace**
- Made available on
  - **Monday**, after the lecture
  - starting in the second week on Mon, Nov 20
- Delivery deadline:
  - **Monday**, one week later at 23:59 CET

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Assignment delivery

- Submit your non-programming assignments in PDF format
- Solutions are to be uploaded in time
  - before 23:59CET on Tuesday one week after announcement
- Grading results will be on Brightspace
  - feedback is also provided on **Brightspace**
- Grading penalties apply
  - No delivery: **100%**
  - Unacceptable delivery: **100%**
  - Lecturers and TAs decide on irregular cases

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Assignment delivery (continued)

- What constitutes *unacceptable* delivery?
  - Delivery **after** the deadline
  - **Plagiarism** of another student answers (penalty applies to **all students involved**, disputes to be resolved by BoE)
  - The submission is **unreadable** (e.g., as a failing PDF)
  - The submission documents contain any items that are **scanned from notes or photographed**, e.g., no handwritten solutions will be accepted (use Word/LaTeX!)

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Corner cases

- Exam/lab grades from the last year **can't be** used
  - **Repeating students** should perform all homework as everybody else
  - Please contact me if you have questions about this
- Assignment grades are valid for the same year's resit

Questions about the organization?