POLITECNICO DI MILANO

Computing Infrastructures





Course Introduction

Prof. Gianluca Palermo

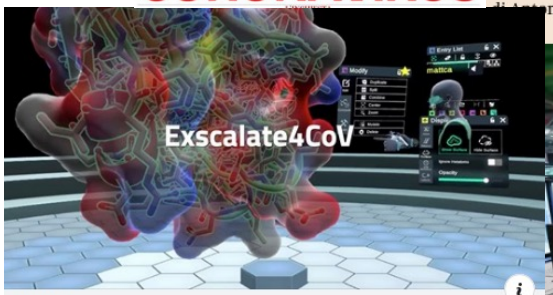
Lecturer - Prof. GIANLUCA PALERMO

- **Email:**
  - gianluca.palermo@polimi.it
  - SUBJECT: **CI25 - <actualSubject>**
- **Phone:**
  - (+39 02 2399) 3552
- **Research:**
  - Embedded and HPC Systems
  - Accelerating SW for Molecular Docking in Drug Discovery applications on HPC architectures
  - GPU programming
- **Teaching Assistant:**
  - Roberto Rocco
    - Fault tolerance in MPI-based HPC applications
    - HPC-Quantum Integration

Virus, supercalcolo a caccia della terapia. «Testeremo 500 miliardi di molecole»

Progetto guidato da Dompé. Già in corso lo screening su 10mila farmaci esistenti. Al Politecnico di Milano il compito di accelerare il processo computazionale

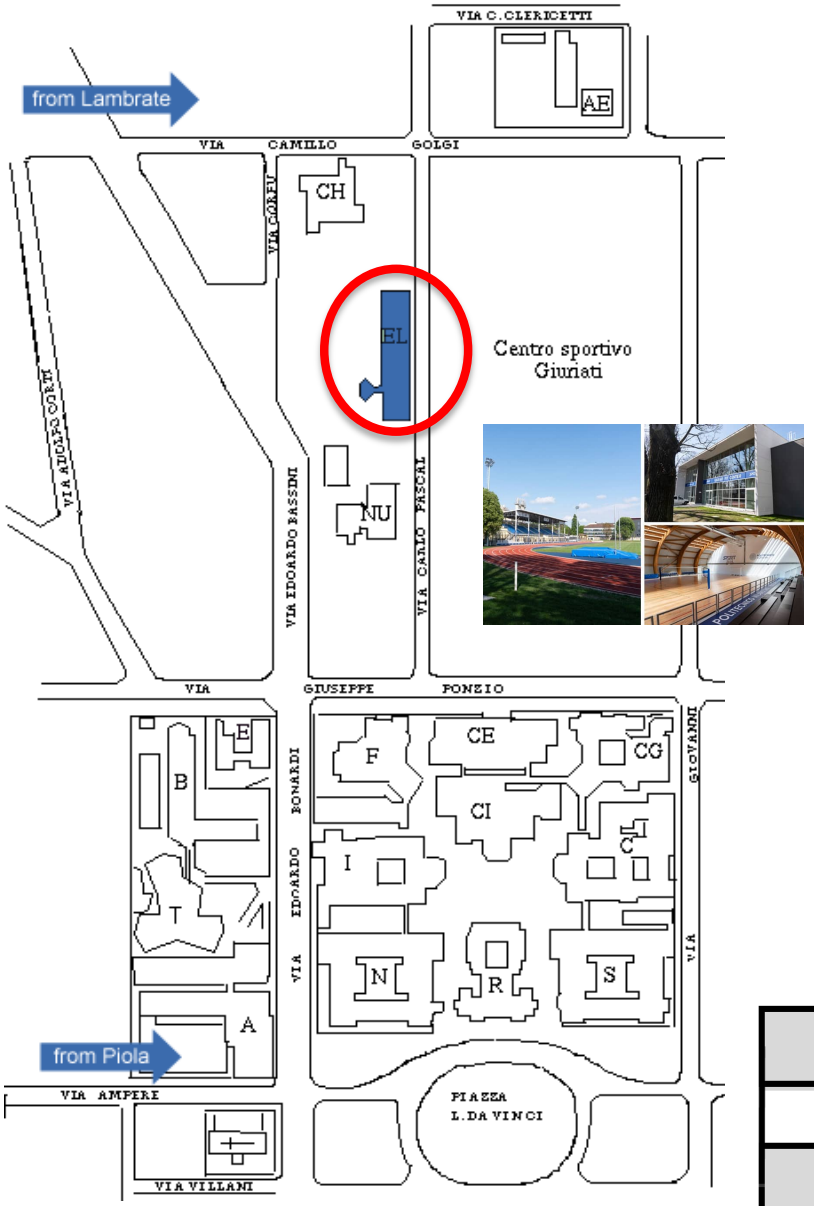
di Antonio Larizza



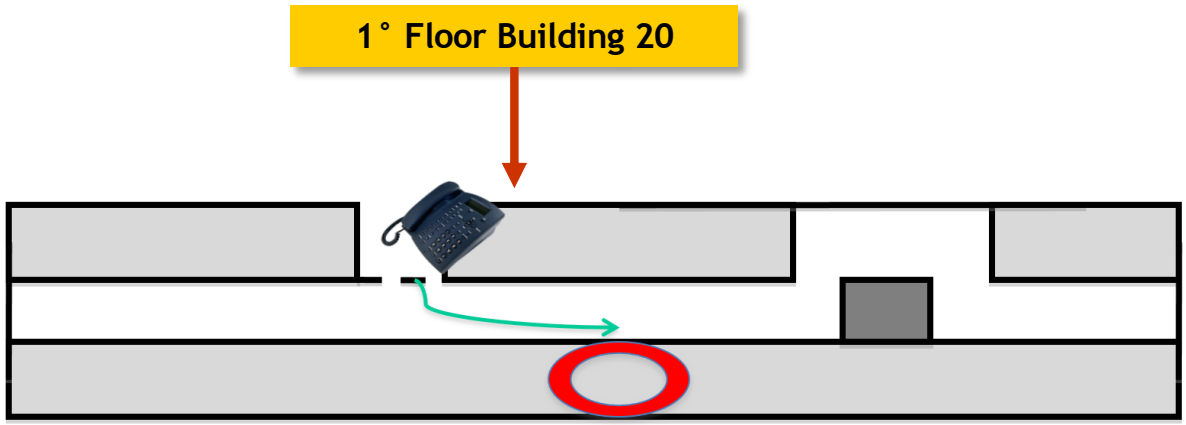
CINECA.IT

Exscalate4CoV HPC platform wins 3 million euro EU funding to hunt for new drugs against Coronavirus pandemic

Office Hours



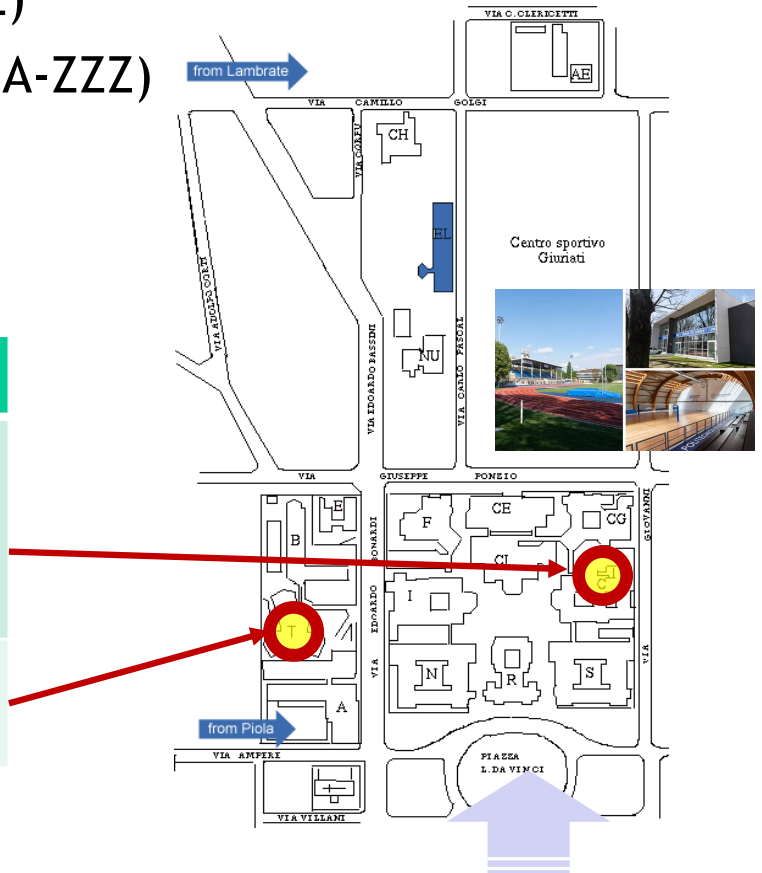
- Office
  - DEIB - Dipartimento di Elettronica, Informazione e Bioingegneria
  - Building 20 – 1st Floor – Room 124
  - On request
- Microsoft Teams:
  - Asynchronous and Remote Interactions with students



Classes of the course

- Students:
  - Cyber Risk Strategy and Governance (A-ZZZ)
  - High-Performance Computing Engineering (A-ZZZ)
  - All the others (A-DZZ)
    - I.e. CSE, MUSIC, BIO, TEL, MNG

	TIME	ROOM
Monday	**14.15-16.15**	5.0.1
Tuesday	**12.15-14.15**	T.2.1



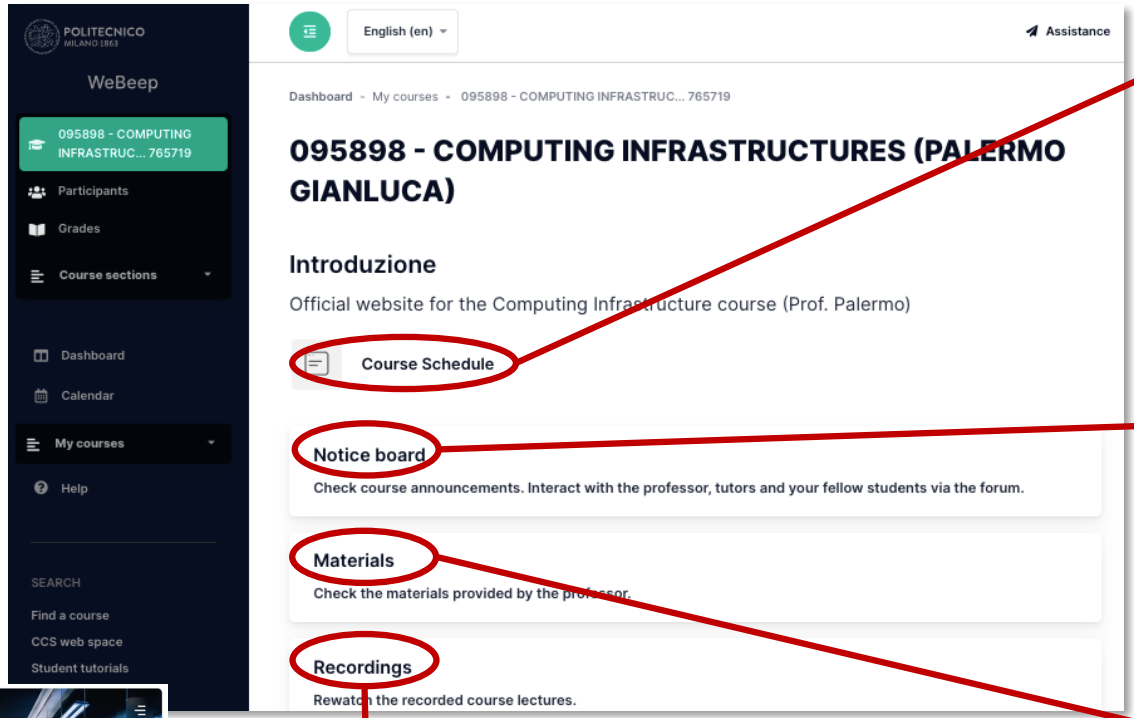
webex by CISCO

https://politecnicomilano.webex.com/meet/gianluca.palermo

NOT USED UNLESS THERE ARE SPECIFIC NEEDS

WEBEEP

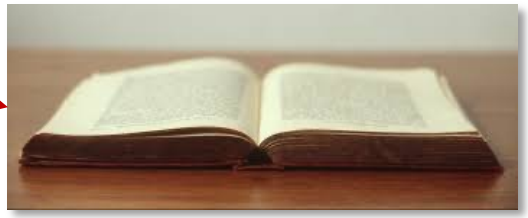
- Central Point Of Synchronization for the course



Dates, Topic, Link to Material

Announcements

Forum



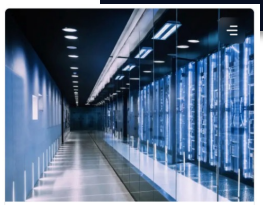
Books

Slides

Exercises

Additional Readings

Exams



095898 - COMPUTING INFRASTRUCTURES (PALERMO GIANLUCA) [2023-24]

2023-24

See Next Slide

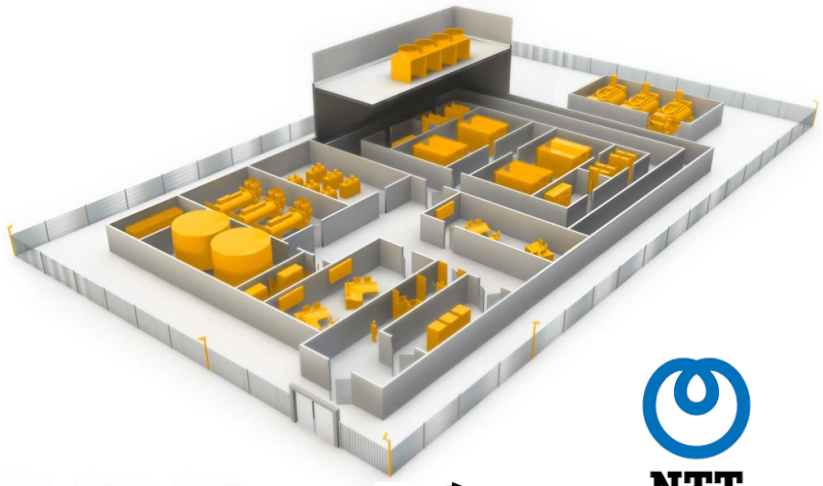
VIDEO OF THE LECTURES

- Lectures will be recorded and made available
  - WEBEEP->Schedule
- **HOWEVER, the course is IN PRESENCE!**
  - **Videos are not thought for offline use**

- Videos on previous editions are also be available
  - AY 2022-2023 /2023-2024
    - Same content, a few updates on the slides & material
  - AY 2020-2021
    - Recorded during pandemic (with Prof. Roveri)

Introduction to the course

- Modern large-scale datacenters require the seamless integration of different components - applications, computation nodes, storage devices, and networks - into one computing infrastructure.



- The course covers the basics of current datacenters architectures, ranging from the analysis of the single components to the global infrastructure.

Why should matter? (Some Examples)

Understand Infrastructure Complexity: Stress the interplay of networking, power, cooling, and hardware IT infrastructure.

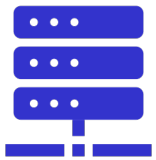
Scalability and Resource Planning: In the context of expansion strategies, as computational needs grow (e.g., HPC clusters with more nodes or GPUs for AI workloads), the supporting infrastructure must grow with it.

Multidisciplinary Nature of the Engineering Elements involved: Show the role of mechanical/electrical engineering aspects (for cooling, power) and industrial designers (for layout, maintenance optimization, availability) in relation to CSE/HPC requirements.

Engineering Constraints: Cooling and power design decisions affect hardware choices (e.g., density of racks, GPU-based computing). Importance to understand which innovation opportunity can help in moving such constraints.

Final Goal: Understanding datacenter infrastructure connects theory (like algorithms, distributed computing) with real-world challenges (power, space, cooling). This holistic view equips future engineers to create, operate, and optimize sustainable, high-performance computing systems. **OPEN THE BOX!!!**

The topics of the course



HW Infrastructures:

System-level: Computing Infrastructures and Data Center Architectures, Rack/Structure;

Node-level: Server (computation, HW accelerators), Storage (Type, technology), Networking (architecture and technology);

Building-level: Cooling systems, power supply, failure recovery

SW Infrastructures:

Virtualization: Process/System VM, Virtualization Mechanisms (Hypervisor, Para/Full virtualization)

Computing Architectures: Cloud Computing (types, characteristics), Edge/Fog Computing, X-as-a service

Methods:

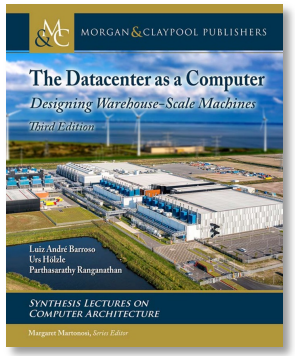
Reliability and availability of datacenters (definition, fundamental laws, RBDs)

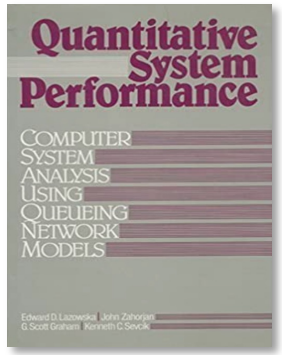
Disk performance (Type, Performance, RAID)

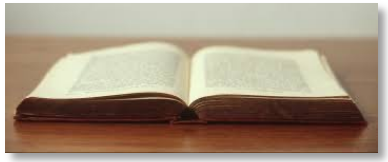
Scalability and performance of datacenters (definitions, fundamental laws, queuing network theory)

Bibliography

- Luiz André Barroso and Urs Hölzle, **The Datacenter as a Computer: Designing Warehouse-Scale Machines. 3rd Edition (2018)**
- Edward D. Lazowska, John Zahorjan,G. Scott Graham, Kenneth C. Sevcik, **Quantitative System Performance: Computer System Analysis Using Queueing Network Models. (Ch.1-6)**
- ***Additional Material provided in WEBEEP***







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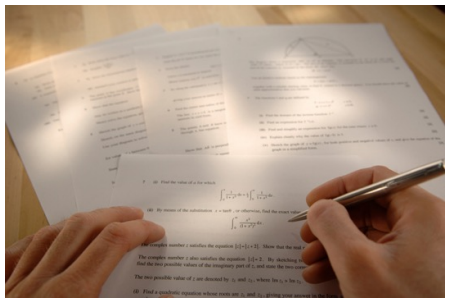
WeBeep

- **Further Readings:**
  - Caesar Wu and Rajkumar Buyya, **"Cloud Data Centers and Cost Modeling"**
  - James Smith and Ravi Nair, **"Virtual Machines - Versatile Platforms for Systems and Processes"**
  - Massimo Lazzaroni Loredana Cristaldi Lorenzo Peretto Paola Rinaldi Marcantonio Catelani **"Reliability Engineering: Basic Concepts and Applications in ICT"**
  - Giuseppe Serazzi, **"Performance Engineering: Learning Through Applications Using JMT"**

PDFs are freely available

Evaluation

- The course will have a **written exam (Closed book)**
- The exam will consist in:
  - a **set of exercises**, i.e., simple problems to solve (similar to the ones that will be covered during the classes)
  - **Open/Closed questions** dealing with general topics covered by the course
- *An oral examination is possible but **only** at the discretion of the professor*
- *Erasmus/Exchange Students*
  - *We follow the School directives -Oral examination in a different moment w.r.t. the exam*
- Exercises and some previous exams are available
  - (see next slide)



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Exam Structure (Example)

+1/2/59+

True false questions
Correct answer: +1, No answer: 0, Wrong Answer -0.5
Answers must be given on the ANSWER SHEETS. Any box filled here will be ignored. Pay attention to the position (A or B) of the True/False answers, since they are not always in the same position.

Question 1 Data centers requires specialized fire suppression systems.
A False B True

Question 2 In current datacenters, east-west traffic is typically less bandwidth-intensive than north-south traffic.
A False B True

Question 3 Cloud computing does not require the user to manage the underlying hardware infrastructure, instead relying on the cloud provider to manage it.
A True B False

Question 4 RAID 6 offers better random read performance than RAID 5.
A True B False

Question 5 Cloud architectures can help reduce the cost of IT infrastructure by enabling pay-as-you-go pricing.
A True B False

Question 6 In-rack cooling involves placing cooling units directly in the server racks.
A False B True

Question 7 RAID 5 has a higher storage overhead than RAID 4.
A True B False

Question 8 Oversubscription is not used in TOR switches
A False B True

Question 9 A three-tier network architecture is never used in leaf-spine architectures
A False B True

Question 10 Raised floor systems in data centers help with cable management and airflow distribution.
A False B True

10 T/F Questions

+1/3/58+

Exercises
Correct answer: +2, No answer: 0.
The formulas and procedures used to solve the exercises should be included here close to the question. The numeric answer, and only that, must be given on the ANSWER SHEETS. Any number written only here will be ignored. The correct number is ONLY a necessary condition for a correct answer. If the formulas are not available after each exercise, they will be considered as not answered.

Question 11
Let us consider a set of requests in the disk queue referring to the following cylinders of the disk: 65, 23, 50, 8, 39. Consider the initial position of the disk head at cylinder 52 and it is moving from inside (lower cylinder number) to outside (higher cylinder number). If no further requests arrive, write the order of the served requests (from the first to the last) if the disk head scheduling algorithm adopted is SCAN? Use the cylinder number to refer to the request.

Question 12
A company uses a computing system composed of three servers: one front-end server and two back-end servers. The system remains operational even if one of the two back-end servers fails. In all other cases, the system is considered offline. All servers have a Mean Time To Failure (MTTF) of 8 months. (i) Compute the probability that at least one of the three servers fails within the first 40 days, and (ii) compute the overall reliability of the computing system after 40 days. *Notes: Use at least 4 decimal places for each intermediate calculation.*

6 Exercises

+1/4/57+

Question 13
A company uses a distributed data storage system composed of five storage units, organized in a *primary* and *secondary* storage groups, according to the following scheme: (i) Two redundant *primary* storage units (S_1 and S_2), meaning that the system continues to work as long as at least one of the two remains operational; (ii) Three *secondary* storage units (S_3, S_4, and S_5) in a configuration that requires that all three secondary units must be operational; (iii) Both storage groups should be operational to have the data storage system working. Each storage unit has the following parameters: Mean Time To Failure (MTTF) = 8 months; Mean Time To Repair (MTTR) = 5 day. Compute the overall availability of the system. *Notes: Use at least 5 decimal places for each intermediate calculation.*

Question 14
You have been assigned the responsibility of optimizing the web server of your company. Through the analysis of your system logs, you have collected the following data (assume that this data is gathered during the peak hour, i.e., T= 1h, on a representative business day).

Number of completed requests C= 10000
Average system utilization U=0.5

What is the system throughput X and the requests service demand D?

+1/5/56+

Question 15
Considering the system described in Question 14, what is the maximum throughput that the system can achieve?

Question 16
Given the system described in Question 14, assume an expected peak workload growth of 4x (i.e. four times more requests within the same time interval). Determine the minimum number of additional servers required to ensure that the system utilization does not exceed 60%. Assume that all new servers have the same configuration as the existing ones and that the incoming requests are evenly distributed across all servers. The answer should include the *total number of servers* required, including the original one.

Overall Grade
(10*1) + (6*2) + (5+5)

+1/6/55+

Open Questions
Correct answer: +5, No answer: 0. Points are modulated considering the written text
Write the answer using ONLY the space available in the boxes on the ANSWER SHEETS. The answers should be readable by the professor. Unreadable answers will be considered wrong.

Question 17
⇒ Explain the concept of Wear Leveling in the context of SSD.

Question 18
⇒ Discuss the concept of Datacenter Availability, and define what are the differences among the Tier Levels established by the Uptime Institute.

!!!ANY ANSWER PROVIDED ON THIS PAGE WILL BE IGNORED!!!
If needed, you can use the space hereafter to organize your answer.

2 Open Questions

+1/8/53+

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Answer Sheets (Page 2)

Question 18
⇒ Discuss the concept of Datacenter Availability, and define what are the differences among the Tier Levels established by the Uptime Institute.

+1/7/54+

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Answer Sheets (Page 1)

First Name (CAPITAL LETTERS): .....
Last Name (CAPITAL LETTERS): .....
Student ID (Codice Persona): .....

Question 17
⇒ Explain the concept of Wear Leveling in the context of SSD.

+1/9/52+

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Answer Sheets (Page 3)

Student ID (Codice Persona): .....

True/False Questions

Question 01 : A B
Question 02 : A B
Question 03 : A B
Question 04 : A B
Question 05 : A B
Question 06 : A B
Question 07 : A B
Question 08 : A B
Question 09 : A B
Question 10 : A B

Exercises

Question 11 : .....
Question 12 : .....
Question 13 : .....
Question 14 : .....
Question 15 : .....
Question 16 : .....

Answer Sheets

Exam Statistics from 2023-2024

- Data on June-July-September-January exams
  - February not yet finalized
- Some number
  - 231 students passed (358 overall “formally attending”)
    - 40 still under evaluation
  - 328 exams corrected
    - Average exam per student passed: 1.41
    - Rejected grade by the student: 19.5%
    - Average grade: 25.7
      - Distribution: See plot