

Indian Institute of Technology Madras
ZANZIBAR CAMPUS

Z5007 · PROGRAMMING AND DATA STRUCTURES · MTECH CORE

Welcome to Programming and Data Structures

Lecture 1: Course Orientation · Monday 5 October 2026

Dr. Innocent Nyalala | MTech Semester 1 | IIT Madras Zanzibar

Today's Plan: 50 Minutes

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1. (0–5 min) Welcome, and who I am
2. (5–15 min) Getting to know you, and our expectations of each other
3. (15–23 min) Why this course: purpose, outcomes, careers, a real example
4. (23–29 min) How the course runs: textbook, topics, weekly rhythm, key dates
5. (29–39 min) Grading: every component, its weight, its date and what it covers
6. (39–44 min) Rules: attendance, integrity, exams, AI tools, late work
7. (44–50 min) Warm-up game, what to do before Wednesday, questions

Course Orientation: Programming and Data Structures

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→ **Welcome and Introductions**

Why This Course

How the Course Runs

Grading

Rules and Expectations

Warm-up Game and Next Steps

About Your Instructor

IIT Madras Zanzibar



Dr. Innocent Nyalala

Assistant Professor, Data Science and AI
Head, SAAIL Lab

innocent@iitmz.ac.in

E **Education**

PhD (Engineering) and MSc (Computer Science and Technology), Nanjing Agricultural University, China

R **Research**

computer vision and machine learning for agriculture: depth imaging, volume estimation, clove grading

L **SAAIL Lab**

Sustainable AI for Agriculture and Intelligent Livelihoods, IIT Madras Zanzibar

T **Teaching here**

Data Mining, Database Management Systems, Big Data Lab, and this course

1,235+	15	35	Tue 2–4 pm
citations	h-index	peer-reviewed outputs	office hours

Your Turn: Let's Get to Know Each Other

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30 seconds each: please tell us

1. Your name, and what you like to be called
2. Where you are from, and where you studied
3. Your background: CS, engineering, maths, other?
4. Have you taken a data structures course before?
5. One thing you want from this course or MTech

Quick show of hands

- Who has written Python before?
- Who has implemented a linked list?
- Who has heard of Big-O?
- Who has done a coding interview?

Expectations Go Both Ways

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What I expect from you

- ✓ Arrive on time, having read the chapter
- ✓ Write code every week, not just read it
- ✓ Ask questions, especially 'silly' ones
- ✓ Be honest in everything you submit

What you can expect from me

- ✓ Clear slides, examples, all on Google Classroom
- ✓ Marked work back within about a week
- ✓ Fair grading; no rule changes without notice
- ✓ Office hours, and replies to email

Your turn, on a card (anonymous): write ONE thing you expect from this course and ONE thing you are worried about. I will collect the cards and respond to them on Wednesday.

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What Is This Course For?

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Purpose: to organize data so programs run fast and scale, and to prove, before running anything, how a program behaves as the data grows.

1

Organize

choose the right structure: arrays, lists, trees, hash tables, heaps, graphs

2

Analyze

predict the cost in time and memory, and prove it is correct

3

Engineer

build it in Python, measure it, make it faster

Course Learning Outcomes: What You Will Be Able to Do

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CLO1	**Analyze**	the time and memory cost of algorithms using Big-O, recurrences and amortized analysis
CLO2	**Implement**	arrays, stacks, queues, linked lists, trees, hash tables, heaps and graphs in Python
CLO3	**Prove**	that algorithms are correct, and reason about lower bounds such as sorting's n log n
CLO4	**Design**	solutions using sorting, recursion, dynamic programming, greedy and graph algorithms
CLO5	**Evaluate**	real performance: profile, benchmark and choose between structures with evidence
CLO6	**Apply**	these tools to large, real datasets, including streaming, randomized and parallel methods

How This Course Helps You: MTech, Internships, Jobs, Problems

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M

Your MTech

Data Mining, Big Data, Deep Learning and your thesis all assume efficient data handling

I

Internships

technical interviews are largely data-structure and algorithm problems

J

Jobs

data engineers, ML engineers and backend developers choose structures daily

Z

Local problems

routing across Unguja, Swahili text search, clove price monitoring

In short: this is the course that turns 'I can code' into 'I can build software that scales'.

A Real Example: Three Correct Programs for One Question

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Question: 1,000,000 transaction IDs. Is any ID duplicated? (True or False)

A **Compare every pair**

```
for i in range(n):
  for j in range(i+1, n):
    if a[i] == a[j]:
      return True
return False
```

checks all pairs: about $n^2/2$

B **Sort, then check neighbours**

```
b = sorted(a)
for i in range(n - 1):
  if b[i] == b[i+1]:
    return True
return False
```

sorting costs about n log n

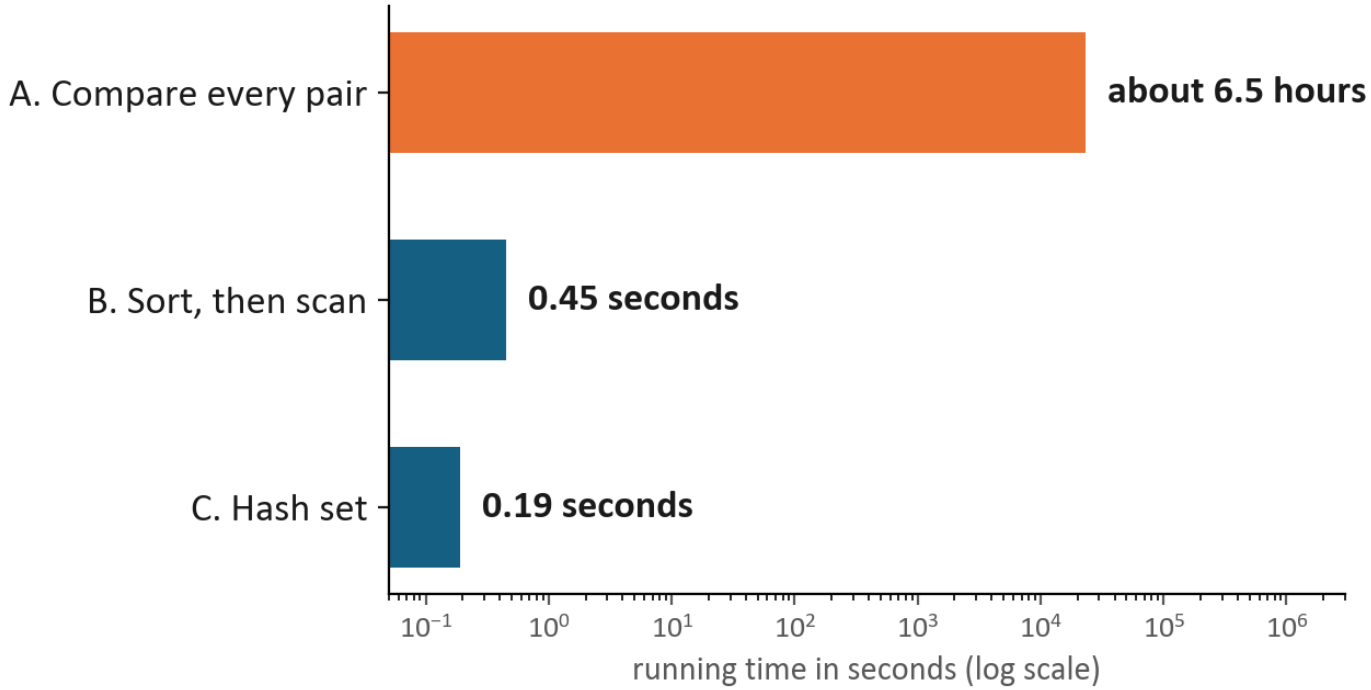
C **Remember what you've seen**

```
seen = set()
for x in a:
  if x in seen:
    return True
  seen.add(x)
return False
```

one pass: about n, uses memory

Guess: which program is fastest for 1,000,000 IDs, and by how much?

The Result: Program A Takes Hours, B and C Take Under a Second



C is ~120,000× faster

than A, on the same laptop, with the same answer

Double n, A takes 4×

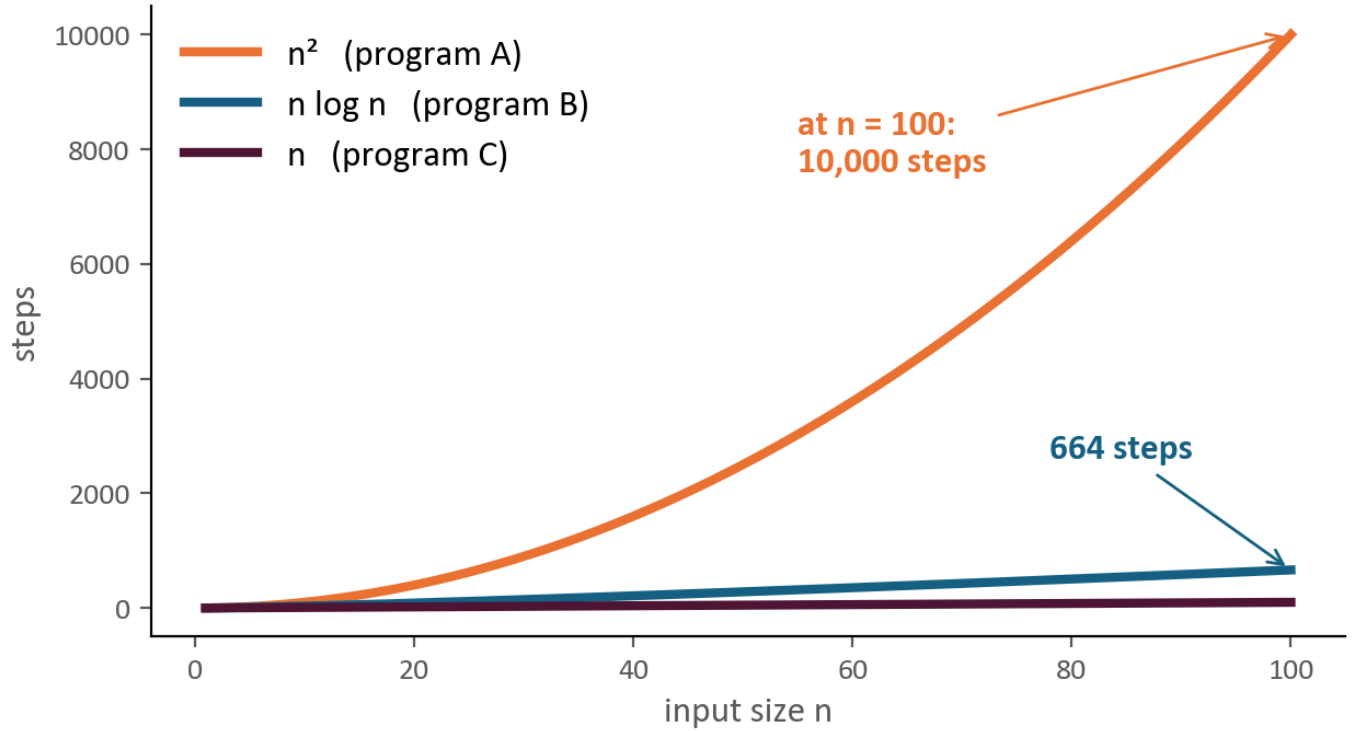
the signature of n^2 growth: it explodes

C pays in memory

it stores every ID it has seen: time versus memory

How measured: B and C timed on 1,000,000 IDs. A timed on 2,000, 4,000 and 8,000 IDs, then extended by its n^2 pattern. One laptop, pure Python.

Why the Gap Grows: How Work Increases With Data



Input size n	A: n^2	B: n log n	C: n
100	10,000	664	100
10,000	100 million	132,877	10,000
1,000,000	1 trillion	~20 million	1 million

Wednesday: Big-O, the language for this.

Key idea: for big data, how work GROWS matters more than how fast your computer is.

These Structures Power Systems You Use Every Day

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B · B-trees · Ch 9

database indexes find one row among millions in a few disk reads

H · Hash tables · Ch 11

every Python dict and set: program C's 0.19 seconds

G · Graphs · Ch 14–15

route finding: Stone Town to Nungwi on the road network

T · Tries

autocomplete: suggesting the next word as you type

P · Heaps · Ch 13

priority queues: schedulers, shortest paths, top-k

F · Bloom filters

databases skip disk reads for keys that are certainly absent

Did Data Structures Before? Same Topics, Harder Questions

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An undergraduate course asks

- ? How does a heap work?
- ? Can you implement merge sort?
- ? What is a hash table?
- ? Run BFS on a small graph

This MTech course asks

- ? Prove building a heap takes O(n) time
- ? Why can no comparison sort beat n log n?
- ? What happens to a dict under bad keys?
- ? Route across all of Zanzibar from map data

Done it before? you move faster early, and lab extension problems are for you. New to it? Weeks 1–3 are your catch-up time.

The Depth Ladder: Every Topic Climbs Three Steps

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Climb every topic

Example: the heap (Chapter 13)

STEP 1

Implement

build push and pop for a heap; test them

tested in: Labs

STEP 2

Prove

show that building a heap from n items is O(n)

tested in: Quizzes, theory exam

STEP 3

Engineer

top 100 clove prices from 10 million records, in fixed memory

tested in: Labs, project

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Textbooks: We Follow the Core Book Chapter by Chapter

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C

Core: Canning, Broder & Lafore (2022)

Data Structures & Algorithms in Python. Addison-Wesley.

our spine: followed chapter by chapter, Ch 1–16

R

Reference: Skiena (2020)

The Algorithm Design Manual, 3rd ed. Springer.

dynamic programming, greedy, A*, randomized algorithms

O

Optional: Cormen, Leiserson, Rivest & Stein (2022)

Introduction to Algorithms, 4th ed. MIT Press.

full proofs, when you want the rigorous version

Habit: read the chapter before the lecture. I announce it at the end of each class.

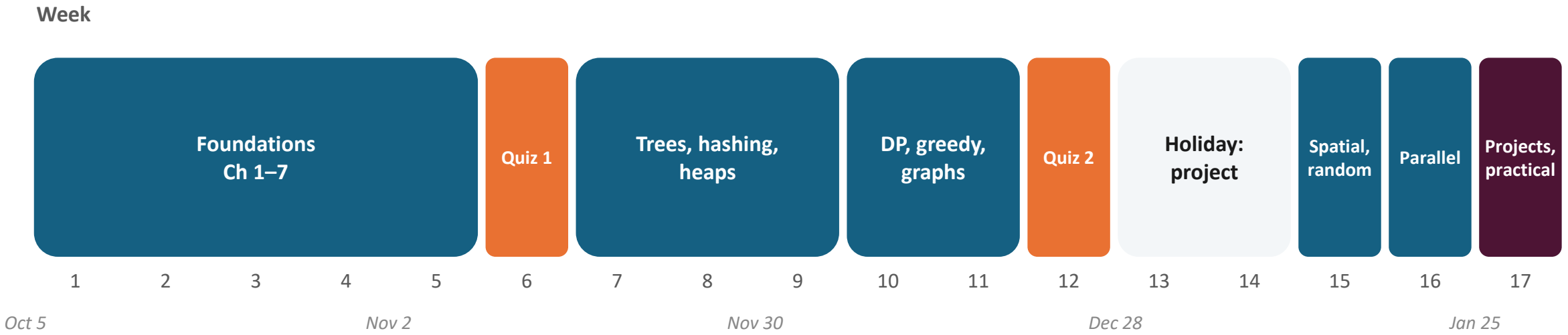
What We Cover, Week by Week

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Weeks	Topics	Source	Tested in
1–3	Analysis (Big-O), arrays, simple sorting, stacks and queues	Ch 1–4	Quiz 1
4–5	Linked lists, recursion, advanced sorting	Ch 5–7	Quiz 1
7–9	Binary trees, 2-3-4 trees, AVL and red-black, hash tables, heaps	Ch 8–11, 13	Quiz 2
10–11	Dynamic programming, greedy algorithms, graphs	Skiena; Ch 14–15	Quiz 2 (not graphs)
13–14	Holiday: independent study, project sprint	Ch 14–15	ICA 4 (Thu 14 Jan)
15–16	Spatial structures, randomized and parallel algorithms	Ch 12, 16; Skiena	End-semester
17	Project presentations, practical exam	everything	Practical

End-semester exams cover the whole course.

The Semester at a Glance: 17 Weeks



1. **Teaching:** Monday 5 October to Thursday 28 January
2. **Holiday study weeks:** Weeks 13–14 (Dec 28 to Jan 8): project work; ICA 4 on Thu 14 Jan
3. **End-semester exams:** 1–5 February 2027

Your Weekly Rhythm: Four Lectures and One Lab

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Mon	Wed	Thu	Thu	Fri
9:00–9:50	11:00–11:50	10:00–10:50	2:00–4:40	11:00–11:50
Lecture	**Lecture**	**Lecture**	**Lab**	**Lecture**

Every lecture has four beats

1. **Concept** — one idea, built from zero
2. **Example** — worked by hand, then in Python
3. **Visualize** — watch the structure change
4. **Exercise** — you solve it; solution follows

and Google Classroom: bring a charged laptop to every class; all materials are posted on Google Classroom.

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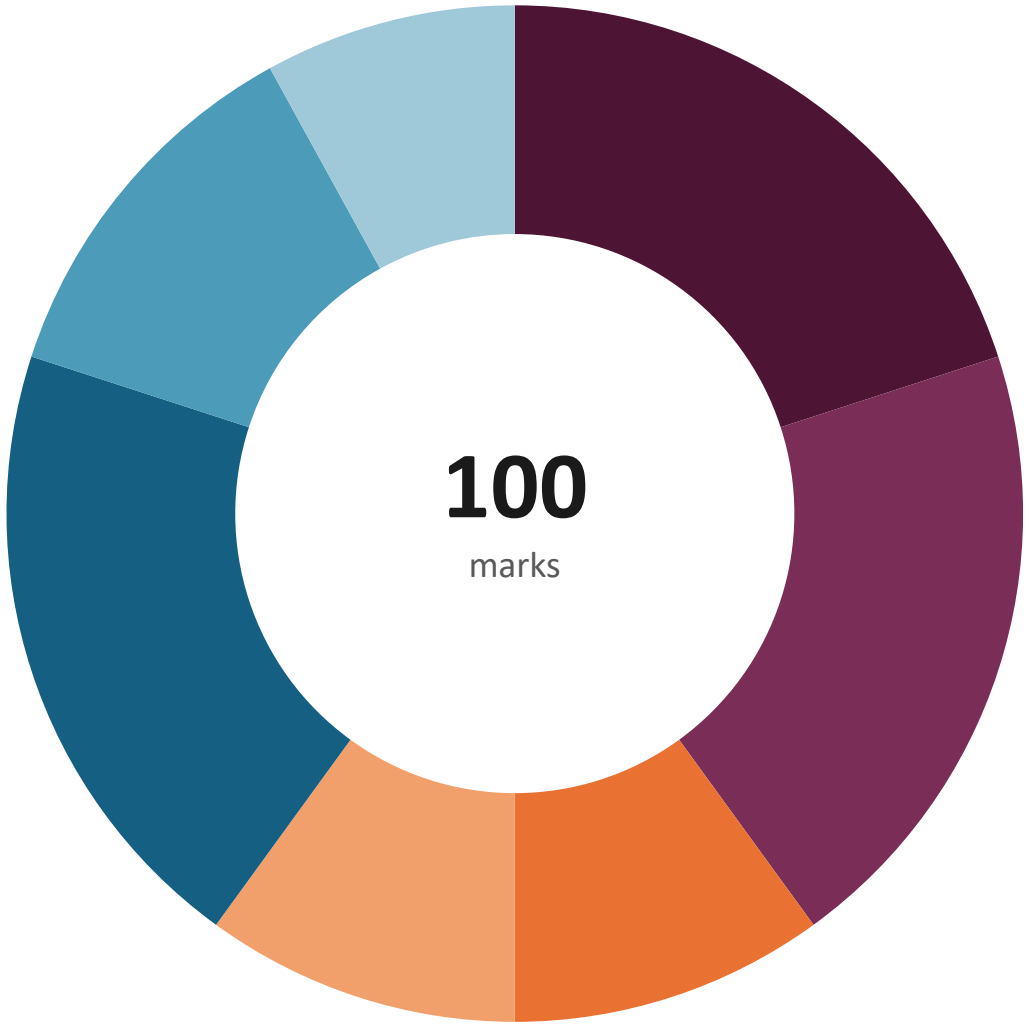
Warm-up Game and Next Steps

Grading: Every Component, Weight, Date and Coverage

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Component	Weight	When	What it covers	Format
Quiz 1	10%	Nov 12–14 (institute window)	Weeks 1–5 · Ch 1–7	Written, closed book
Quiz 2	10%	Dec 22–24 (institute window)	Weeks 7–11 · Ch 8–11, 13, DP, greedy	Written, closed book
In-class assignments (4 ICAs)	12%	Thu labs, 2:00–2:45: Oct 22, Nov 5, Dec 3, Jan 14	the block just finished	Coding in class, offline, auto-tested
Labs	8%	every Thursday	that week's topic	Best 9 of 11 graded labs
Project (pairs)	20%	Nov 6 → Jan 28	your chosen problem	Proposal, checkpoint, report, viva
End-sem practical	20%	Thu 28 Jan, lab	whole course	Coding, offline, 2 h 40 min
End-sem theory	20%	Feb 1–5 timetable	whole course	Written, closed book
Total	**100%**			

Grading at a Glance: 60% Is Supervised



60% supervised: quizzes 20 + end-sem practical 20 + end-sem theory 20

20% project, with an individual viva for each member

20% in-class coding: ICAs 12 + labs 8

The Two Quizzes: Dates, Coverage and Format

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Quiz 1

10%

Nov 12–14 window

Weeks 1–5
Ch 1–7: analysis, arrays, sorting, stacks, queues, linked lists, recursion

Quiz 2

10%

Dec 22–24 window

Weeks 7–11
Ch 8–11, 13: trees, hashing, heaps;
dynamic programming and greedy

Format of both quizzes

- ✓ Written, closed book
- ✓ No phones, laptops or notes
- ✓ Concepts, tracing, analysis, design
- ✓ Like our in-class exercises

Missed a quiz? only a documented medical or family emergency, applied for through the institute's process, allows a make-up. Otherwise it scores zero. Exact day and time: announced on Google Classroom.

The End-Semester Exam (40%) Has Two Halves

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Practical · 20%

Thursday 28 January, 2:00–4:40

- ✓ Offline: no internet, no AI tools
- ✓ Implement a structure from scratch
- ✓ Choose and build the right structure
- ✓ Make a slow program fast, explain why

marked by hidden tests: correctness 60, speed 20, written analysis 20

Theory · 20%

Written paper, Feb 1–5 exam timetable

- ✓ Proofs of correctness
- ✓ Running-time analysis
- ✓ Tracing algorithms by hand
- ✓ Design: choose and justify a structure

covers the whole course

Rehearsal: mock practical in the lab on Thursday 10 December, same rules.

In-Class Assignments (12%) and Labs (8%)

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In-class assignments · 12% (3% each)

ICA 1 — **Weeks 1–3: Big-O, arrays, sorts, stacks**
Thu 22 Oct, 2:00–2:45 pm

ICA 2 — **Weeks 3–5: lists, recursion, sorting**
Thu 5 Nov, 2:00–2:45 pm

ICA 3 — **Weeks 7–10: trees, hashing, heaps**
Thu 3 Dec, 2:00–2:45 pm

ICA 4 — **Weeks 10–12: DP, greedy, graphs**
Thu 14 Jan, 2:00–2:45 pm

Labs · 8%

best 9

of 11 graded labs count

- ✓ Build a structure, then measure it
- ✓ Extension problems for the keen
- ✓ Missed one? Already covered
- ✓ Submit on Google Classroom

Submission: everything is submitted on Google Classroom, before the stated deadline.

The Project (20%): Real Data, Real Structures, Measured

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Form pairs
by Fri 16 Oct

Proposal
Fri 6 Nov
3%

Checkpoint
Fri 18 Dec
5%

Report
Fri 22 Jan

Present + viva
Jan 25–28
12%

1 **Real data**

public or local datasets: OpenStreetMap, Swahili text, market prices

2 **Structures that matter**

justify each structure against at least one alternative

3 **Measured**

benchmarks on growing inputs, with the complexity explained

4 **Individual viva**

each member answers questions on the whole project

Project Ideas: Start Thinking Now

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1. **Zanzibar route planner**
   shortest paths on OpenStreetMap roads
2. **Swahili spell checker**
   trie + edit distance on a Swahili corpus
3. **Swahili news near-duplicates**
   MinHash and LSH vs. brute force
4. **Money-transfer graph analysis**
   cycles and PageRank on transfers
5. **Spice and clove price monitor**
   top-k and sliding windows on a stream
6. **Mini key-value store**
   B-tree index + LRU cache
7. **Crop-image similarity search**
   k-d tree vs. LSH on image features
8. **Ferry or clinic queue simulation**
   priority queues, event simulation
9. **Produce collection routing**
   greedy vs. DP on village locations
10. **Sorting data bigger than RAM**
    external merge sort, parallel speedup

Your own idea? Welcome, if it meets the same rules.

From Marks to Your Final Grade

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S	A	B	C	D	E	U
10 points	9 points	8 points	7 points	6 points	4 points	0 points
pass	*pass*	*pass*	*pass*	*pass*	*pass*	*fail*

1. **Your marks out of 100**
   from the grading table
2. **Cut-offs set at semester end**
   from class performance, per institute policy
3. **Letter grade S to U**
   enters your CGPA

No grade at all if: you fall below the institute's attendance requirement, or commit an integrity violation in an exam.

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Attendance and Classroom Conduct

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A Attendance

taken in every lecture and lab; below the institute minimum, you can be barred from the end-semester exam

T Punctuality

be on time; if late, enter quietly without disturbing the class

P Phones and laptops

phones silent and away; laptops only for class work

R Respect

every question is welcome; nobody laughs at a question in this room

Academic Integrity: No Copying, No Cheating

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ICAs, labs, project

- ✓ Discuss ideas freely with classmates
- ✓ Never share or copy code
- ✓ Cite any code or idea you take from outside
- ✓ Matching submissions: both score zero

Quizzes and exams

- ! No phones, smart watches, notes or talking
- ! No looking at others' papers or screens
- ! Cheating: zero for that exam
- ! And a report to the disciplinary committee

Stuck is normal. Copying is not. If you are stuck, come to office hours (Tuesday 2–4 pm) or email me before the deadline. I will help.

AI Tools: A Tutor, Not a Ghostwriter

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✓ Allowed

- Explain a concept you are stuck on
- Help find a bug in code you wrote
- Generate extra practice problems
- Declare use in one line

✗ Not allowed

- Submitting code you cannot explain
- Any AI or internet in quizzes or exams
- Pasting a question and submitting the output
- Hiding that you used AI

The test: I can point at any line you submit and ask why it is there, what it costs and what happens when the input doubles. If you cannot answer, the work scores zero.

Late Work, Communication and Getting Help

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L

Late work

minus 10% per day; not accepted after 3 days. Emergencies: tell me BEFORE the deadline.

G

Google Classroom

slides, lab notebooks, announcements, quiz and ICA times. Class code given in class today.

E

Email

innocent@iitmz.ac.in for anything personal; put Z5007 in the subject line.

O

Office hours

Tuesday 2:00–4:00 pm. Come early in the semester, not the week before exams.

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Warm-up Game: Guess My Number (4 minutes, in pairs)

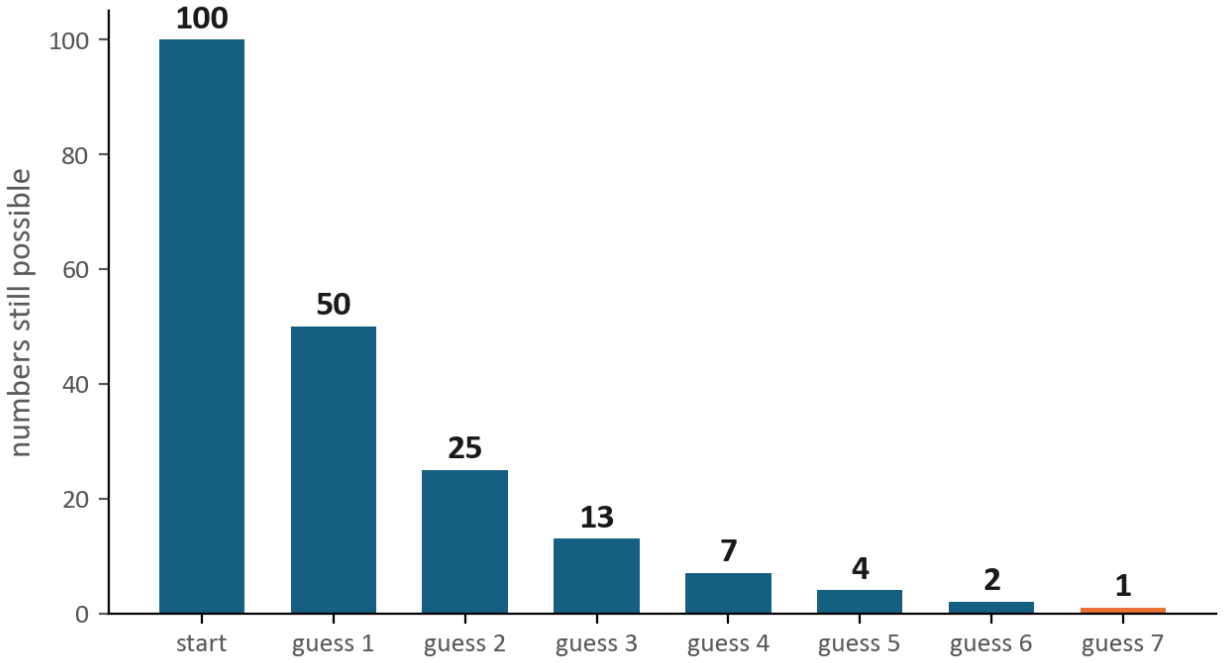
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IN-CLASS GAME

Rules: your partner secretly picks a number from 1 to 100. You guess. They answer only **higher**, **lower** or **correct**. Play twice, then swap.

1. How many guesses did you need? What was your strategy?
2. Strategy A: guess 1, 2, 3, ... in order. What is the Worst-case number of guesses?
3. Strategy B: always guess the middle of what is left. What is the worst case?
4. If the range were 1 to 1,000,000, what would the worst case be for A? And for B?

Solution: Halving Beats Counting, by a Lot



Range	A: count up	B: halve
1 to 100	100 guesses	7 guesses
1 to 1,000	1,000	10
1 to 1,000,000	1,000,000	20

A is linear search: up to n guesses
B is binary search: about $\log_2 n$ guesses

Why it matters: halving only works because the numbers are IN ORDER. Keeping data organised so it is fast to search is the idea behind sorted arrays, binary search trees and B-trees.

Before Wednesday: Four Things To Do

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1 **Join Google Classroom**

code is **q3qmenl2**

2 **Read Chapters 1–2**

Canning, Broder & Lafore: overview and arrays

3 **Install the tools**

Python 3.12+, VS Code, Jupyter; problems? office hours Tue 2–4 pm

4 **Wednesday: 15-min warm-up quiz**

printed, about 10 questions, NOT graded: do not study for it

This week: Wed Big-O analysis · Thu foundations of data structures · Fri Big-O made simple · Labs start Thu 15 Oct

Summary and Questions

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We know each other

office hours Tue 2–4; Google Classroom for everything

Purpose

organise, analyse and engineer data so programs scale

Grading is fixed

quizzes 20, ICAs 12, labs 8, project 20, end-sem 40

Integrity first

attend, be honest, ask for help early

Questions?

Karibuni IIT Madras Zanzibar

Resources: See It and Learn It

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Visualize the structures

VisuAlgo visualgo.net

animated sorting, lists, trees, hashing, graphs

USF Visualizations cs.usfca.edu/~galles/visualization

step through any structure

Python Tutor pythontutor.com

watch your Python code run, line by line

Algorithm Visualizer algorithm-visualizer.org

animated code for classic algorithms

Learn in depth

MIT 6.006 Introduction to Algorithms ocw.mit.edu

full lectures, notes and problem sets

Problem Solving with DS (Python) runestone.academy

free interactive Python textbook

Python documentation docs.python.org

the official reference for lists, dicts, heapq

Python TimeComplexity wiki.python.org

cost of every built-in operation

Resources: Practice and Reference

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Practice problems

LeetCode leetcode.com

interview-style problems, sorted by topic and difficulty

HackerRank hackerrank.com

data structures and algorithms tracks

NeetCode neetcode.io

curated problem roadmap with video solutions

Exercism exercism.org/tracks/python

Python exercises with mentor feedback

Quick reference

Big-O Cheat Sheet bigocheatsheet.com

costs of common structures and sorts

CP-Algorithms cp-algorithms.com

detailed explanations of classic algorithms

TheAlgorithms github.com/TheAlgorithms/Python

read these AFTER writing your own

Book companion tools Canning, Broder & Lafore

visualization apps that come with our textbook

References and Further Reading

Canning, J., Broder, A. & Lafore, R. (2022). Data Structures & Algorithms in Python. Addison-Wesley. (Core text.)

Skiena, S. S. (2020). The Algorithm Design Manual, 3rd ed. Springer.

Cormen, T. H., Leiserson, C. E., Rivest, R. L. & Stein, C. (2022). Introduction to Algorithms, 4th ed. MIT Press.

Python Software Foundation. Time complexity of built-in operations. wiki.python.org/moin/TimeComplexity