**✅ Session Ground Rules**

**🧑‍🏫 Learning & Participation**

1. **Be Present:** Please join on time and stay for the full session.
2. **Stay Engaged:** Participate actively — ask questions, share thoughts, and collaborate **when prompted.**
3. **Use the Chat Wisely:** Drop questions, but avoid spamming or unrelated messages.

**🎧 Tech Etiquette**

1. **Mute When Not Speaking:** Keep your mic muted unless you’re asking or answering something.
2. **Camera Optional but Encouraged:** If you're comfortable, keep it on — it helps build connection.

**📚 Content & Recording**

1. **No Unauthorized Recording:** Please don’t record or share the session without permission.
2. **Materials Access:** Any slides, code, or recordings (if applicable) will be shared after class.

**🤝 Respect & Inclusion**

1. **Respect All Opinions:** There are no “silly” questions — we’re all here to learn.
2. **Keep It Professional:** No offensive, disrespectful, or disruptive behavior will be tolerated.

**🚨 Support & Issues**

1. **Facing Tech Issues?** Let me or the moderator know in the chat — we’ll try to help immediately.
2. **Missed Something?** Don’t worry, you’ll get resources to review.

**💡 Final Thought:**

“Learning is a team sport — **let's support each other and make the most of our time together**!”

**Phase 2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | 28/06/2025 | Java-1 | 4 | What is Java? Installing and cofiguring Java, Byte code, Compilation Process, Data Types, Operators, Conditional Statements, Looping statements, |
| 2 | 29/06/2025 | Java-2 | 4 | OOPS, Abstraction, Polimerphism, Inheritance, Encapsulation, Access Specifiers, Methods, Constructors**,** |
| 3 | 5/7/2025 | Java-3 | 4 | Static, final, Memory Management, Multi threading, Arrays, String Handling, |
| 4 | 6/7/2025 | Java-4 | 4 | Exception Handling, Collections |
| 5 | 12/7/2025 | Maven | 4 | Java 11 features, Web programming, CS Architecture, **HTTP Protocol**, Servlet Lifecycle, Web Server |
| 6 | 13/07/2025 | JDBC | 4 | Servlet API, Maven, Write first program, Servlet Filters, |
| 7 | 19/07/2025 | Servlet-1 | 4 | Servlet Session management, JDBC API, Servlet with JDBC Example |
| 8 | 20/07/2025 | Servlet-2 | 4 | JDBC CRUD Operations along with Statement , Prepared Statement, Callable Statement, JSP introduction(Scriping tags, implicit objects) |
| 9 | 26/07/2025 | JSP-1 | 4 | Directives, Action Tags |
| 10 | 27/07/2025 | Mongo -1 | 4 | Mongo-1 |
| 11 | 2/8/2025 | Mongo-2 | 4 | Mongo-2 (data modelling, validations, index) |
| 12 | 3/8/2025 | QA and PE project | 4 | Phase end project explaination |
| 13 |  |  | 4 |  |

**12/07/2025**

**Self study:**

**JDK 8 – Functional interface, Lambda expression**

**Java 11:**

Released in Sep 2018 -- LTS

1. Local-Variable syntax for **Lambda parameters**

Introducing var keyword in lambda parameters

1. New String methods

isBlank()

lines()

strip()/ stripLeading()/stripTrailing() 🡪 Unicode aware triming

repeat(n) 🡪

1. Java.nio.file.Files
2. **HttpClient (standardized)**

* They support synchronous and asynchronous calls
* Http 1.1/ and Http/2
* Web sockets

1. **Removed and deprecated**

Jaxb, jax-ws, corba etc

appletviewer, javaws etc

1. **New Garbage collector**

ZGC collector 🡪 as experimental

**What is Internet?**

* Global system of interconnected computer network (**TCP/IP** protocol)
* A network of networks
* Enables communication, file sharing, web browing, email streaming etc

**Key components:**

* **Servers:** Machine that provides resources and services
* **Client:** User’s computer /devices accessing services
* **Routers and Switches –** Manage & direct data flow
* **Protocols:** Rules for communication (HTTP, TCP/IP, FTP)

**Timeline:**

* **ARPANET (1969)**

US military project – small package switched network

* **Email, FTP, Telnet introduced**
  + 1990
* Tim Berners-Lee invents WWW with HTTP and HTML
  + 1995-2000
* Commercialization

2000-2010

* **Web2.0 🡺** social media, cloud computing…
* **Web 3.0 🡪 (**decentralization, AI, IOT)

**Web Programming**

* **Web applications**
  + WEbsites
  + Web apps (gmail, facebook, ….)
  + APIs (Backed services)
* **Technologies?**
  + **Markup Languages** – Presentations of the content (HTML Structure, CSS (styling), XML/JSOn 🡪 data)
* **Database**
  + **Relational DB –** MySQL, PostgreSQL
  + **NoSQL –** MongoDB, Cassandra
* **Programming Language:**
  + Backend – Java, Python, php,ndejs, ruby…..
  + Frontend 🡪 JavaScript, Typescript
* **Business Applications**
  + Domain specific applications 🡪 Ecommerce, banking, CRM, ERP

**Client Server architecture**

The Client (Browser/app) sends a request

The Server processes the request and sends a response

**Presentation logic Business logic DB**

**Two-Tier Architecture**

* Direct communication between client and database server
* Client has the UI + Some business logic
* DB Server stores and manages the data.

Ex.

Desktop application 🡪 client directly connects to the db

**Pros**:

* Simple to build
* Good for small applications

**Cons**:

* Not Scalable
* High load on DB server

**Three-Tier Architecture**

What is it?

Divides applications into three layers

* Presentation layer (client)
* Application layer (Server/business logic)
* Data layer (Database)

Why?

* Better scalability
* Better security
* Easier maintenance

Ex:

* Ecommerce site
  + Submit order 🡪 presentation
  + Order processing logic 🡪 Application (server)
  + Stores order details in DB 🡪 Data layer

**Web server/Application server**

Web server 🡪

* Accepts http requests from client (like browsers)
* Respond with static content

|  |  |  |
| --- | --- | --- |
| **Feature** | **Web server** | **Application Server** |
| Purpose | Handles HTTP requests & responses, serves static content | Provides business logic for applications, can serve dynamic content |
| Content | Static (HTML, CS, JS) | Dynamic , Transactioal, complex apps |
| Protocols | HTTP/HTTPS | RMI, JMS etc |
| Examples | Apache, Nginx, IIS | Tomcat,JBoss/Wildfly, Weblogic.. |

* A Web server can serve static pages quickly
* Application server can also execte java code to build some dynamic pages.

Examples:

* Images, CSS, JS 🡪 web server
* Order processing, DB Intereaction, 🡪 Application server

## HTTP Protocol

HTTP – Hypertext transfer protocol

Foundation of communication on the web, allowing client (browser) and server to exchange information.

* Applicatin layer protocol
* Request response based
* Statless 🡪 Each request is independent of others
* Connectionless 🡪
* Media independent 🡪

Components of http::

1. HTTP Methods

|  |  |
| --- | --- |
| **Method** | **Purpose** |
| **GET** | **Retrieve resource (Safe and idempotent)** |
| **POST** | **Submit data to the server** |
| **PUT** | **Replace a resource** |
| **DELETE** | **Delete a resource** |
| PATCH | Partially update a resource |
| HEAD | Retrive only headers |
| Options | Get supported methodsd |

1. HTTP Request structure
2. HTTP Response Structure
3. HTTP Status codes

1xx 🡪 Informational

2xx 🡪 Success (200 Ok, 201 🡪 Created)

3xx 🡪 Redirections (301 Moved permanently, 302 Foud)

4xx 🡪 Client error (400 Bad request, 404 not found)

Versions of HTTP

* HTTP/1.0 🡪 One request per connection
* HTPP/1.1 🡪 Persistent connections, chunked transfer
* HTTP/2 🡪 Binary, Header compression, Multiplexing
* HTTP/3 🡪 Uses QUIC instead TCP, faster, and secure

# Servlet

Servlet programming🡪 writing java programs that runs on a application server on the web to handle client requests and generate dynamic responses.

Why?

* Before servlets 🡪 CGI scripts 🡪 heavy and slow
* Servlets run inside a java process (servlet container) more efficient.

**What servlet is?**

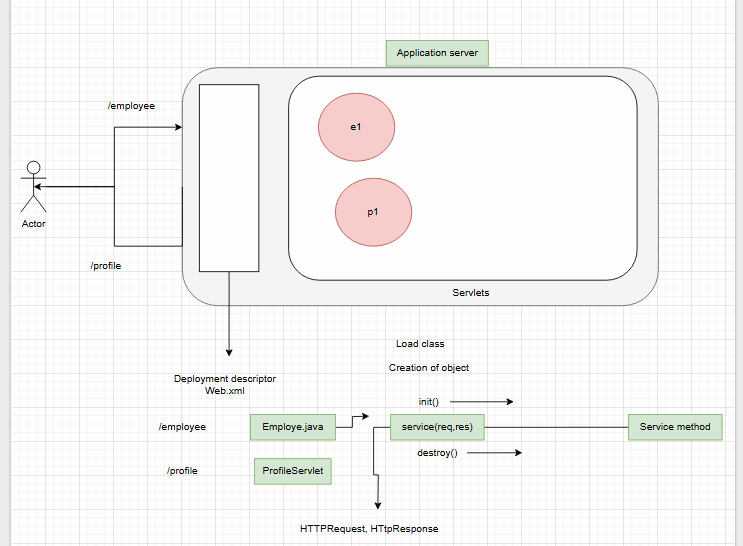
* A servlet is a java class that handles HTTP request & generates HTTP responses.
* Runs in a **servlet container** (Tomcat)
* Acts middle layer (3 layer) allows you to do business logic/ database

**Servlet lifecycle**

Init() 🡪 initialization of servlet

Service() 🡪 Request handling logic

Destroy() 🡪 destroy logic



javax.servlet.Servlet

two things:

serer 🡪 hold all the libraries

**Maven**

Maven is a **build automation** and **project management tool** for java and JVM based projects

Developed by Apche

Handls:

* Compilation
* Packaging
* Testing
* Dependency management
* Deployment

So you don’t have to manually download jars, and write complex build scripts or track dependencies

Why to use maven?

* Standardized project structure
* Makes builds portable
* Easily integrates with CI/CD tools
* Supports lot of plugins to extend functionality

Development workflow:

* Write code
* Pom.xml (define all dependency)
* Run maven command (mvn clean install)
* Get:
  + Compiled code
  + Jar/War file
  + Reports

**Setup project**

1. Download and install maven (<https://maven.apache.org/download.cgi>)
   1. Download zip file
   2. Extract it
   3. Create MAVEN\_HOME environment variable
   4. Include %MAVEN\_HOME%\bin in path variable (just like Java)
2. Download tomcat 8.1 (https://tomcat.apache.org/download-90.cgi) (extract it)
3. Configure eclipse to use tomcat
   1. Servers 🡪 click link 🡪 Select extracted jar 🡺 click finish
4. Configure eclipse to use your maven configuration
   1. Preferences 🡪 Maven🡪 installation 🡪 add 🡪select where you have extracted (maven)
   2. Apply and finish

**06/07/2025**

**Exception Handling**

**What is Exception?**

An exception is an unwanted or unexpected event that occurs during the execution of a program and disrupts the normal flow.

**Why Use Exception handling?**

* To handle errors gracefully, without crashing the program
* To Separate error-handling code from regular code
* To provide meaningful message about error
* To recover from errors and continue execution

**Errors and Exceptions**

* Errors generally cannot be recoverable
  + E.g. OutOfMemoryError, StackOverflowError

Best Practices:

* Catch Specific exceptions, not just Exception
* Always clean up resources in finally or use **try-with-resources**.
* Don’t overuse checked exceptions – only where needed.

**Java Collections framework:**

A set of interfaces and classes,

* Helps you to manipulate group of objects

Why?

Instead of writing your own code for:

* Array that grows dynamically
* Removing duplicates
* Sorting elements

Ready-made, tested, fast and flexible classes.

**Benefits**:

* Reduce development time
* Easy to use and maintain
* Many ready-made datastructurs: List,Set,Queue, Map etc
* Built in algorithms : sort, search, shuffle etc

Iterable

* Root interface for JCF
* Any collections like (List, Set etc) implements Iterable
* It represents group of elements you can hoop over one by one

iterator()

forEach()

for(String name: **names**) {

}

**Collection:**

* Collection is the root interface for all collections in java. (Except Map)
* It extends Iterable, so it already supports iteration
* It represents group of elements.

Common operations:

* Add elements
* Remove Elements
* Check Size
* Check if empty
* Clear all elements
* Convert to an array

**List Interface**

* **Subinterface** of Collection.
* Represents an **ordered collection** of elements
* Duplicates are allowed
* You can access elements by index (position)

LinkedList:

* Backed by doubly-linked list
* Good for frequent insertions and deletions
* Slightly slower for random access.

Set interface:

* Set is subinterface of Collection
* Represents a collection of unique elements
* No **duplicates** allowed
* **Order is not guaranteed** (but some implementations maintain order)

**HashSet**:

* Backed by hash table
* Doesn’t maintain order

**LinkedHashSet**: (maintain insertion order)

* Backed by hasthtable + linked list

**TreeSet**:

* Backed by a Red-Black Tree
* Maintains sorted order (ascending by default)
* Slower than HashSet.
* Set of employee objects (id, name, address, …) , how you sort it using TreeSet?

**Queue:**

* Queue is subinterface of Collection
* Represents a collection of elements in a specific order, usually FIFO.
* Think of it as ticket counter – first person in the line gets served first.

Why?

* Process eleemtns in order of arrival
* Useful for scheduling tasks, messaging, job queues, etc.

**Methods:**

* add(E e) 🡪 Adds an element (throws exception if full)
* offer(E e) 🡪 Adds an element (return false if full)
* remove() 🡪 Removes and return head ( throws exception if empty)
* poll() 🡪 Removes and return head (return null if empty)
* element() 🡪 Returns head without removing (throws exception if empty)
* peek() 🡪 Returns head without removing (returns null if empty)

Implemented class:

* LinkedList
* PriorityQueue – Orders elements by priority (natural)
* ArrayDequeue – (Double-ended queue- acts as both queue and stack)

Map

* Map is not subtype of Collection – its separate interface
* Represents a collection of key-value pairs
* Keys must be unique, but values can be duplicated
* You use it when you want to associate a key to a value -

Why use?

* Data by unique id
  + Student roll no 🡪 name
  + employeeId 🡪 Employee Details
  + Word 🡪 frequency of word

Methods:

* Put(x,y) 🡪 Add a keyvalue pair
* get(k) 🡪 get value by key
* remove(k) 🡪 Remove key-value pair
* containsKey(k) 🡪 check if key exist
* ContainsValue(v) 🡪 check if value exist
* keyset() 🡪 returns set of keys
* values() 🡪 Returns collection of values
* entrySet() 🡪 Returns a set of Map.Entry (key value pair)

Implementaitnos:

* HashMap
* LinkedHashMap
* TreeMap

**05/07/2025**

**Static:**

Used to define variables, methods, blocks, or nested classes that **blong to the class rather than to any specific object**

* Normally , members of class (fields or methods) are belong to the instances (objects)
* But static members belong to the class itself, so they are shared by all instances and can be accessed without creating an object.

**Why Static?**

* To save memory – only one copy exists for the class
* To represent things that are **common** to all objects of the class.
* To allow access without creating an object.

**What is Memory Management?**

Memory Management in java is the process of

* Allocating memory to objects
* Keeping track of allocated memory and
* Automatically reclaiming memory that is no longer needed.

M/R management Is handled mostly automatically (by JVM), and GC (Garbage collector)

Two parts:

1. Heap Memory
2. Stack Memory

There are few smaller regions for internal management.

**Heap Memory:**

* Used for dynamic memory allocation (objects, arrays)
* Whenever you use new keyword to create an object, memory allocated in the heap.
* Managed by Garbage collector.

**Stack Memory:**

* Used for method calls and local variables.
* Each thread gets its own stack.
* Follows LIFO
* Memory is automatically freed when the method call ends.
* Stores
  + Local varaiables (int , float)
  + Reference to the objects (but actual object is on heap)

**Method Area:**

* Stores bytecode, static variuables, method metadata (blueprints)

**Final keyword**

* The final keyword in java is non-access modifier that is used to declare something as constant, non-changeable, non-extendable, depending on where it is applied.
* Final with
  + Variable
  + Method
    - Method cannot be overridden in a subclass
  + Class
    - Cannot be extended (inherited)

**Why?**

* To create constants (Unchangeable variable)

**Multi-Threading**

* What is Multithreading?
* Process vs Thread
* Where threads are stored in memory
* Thread Lifecycle
* Race Conditions
* Synchronization
* Inter-Thread communication (Wait/notify)

**What is Multithreading?**

Multi-threading means running multiple threads concurrently within a single program (process)

* Thread is the smallest unit of execution
* Java supports multi-threading to perform multiple tasks at the same time- increasing resource utilization and performance.

**Why Use Multithreading?**

* Better CPU Utilization
* Improved responsiveness of program
* Useful for task like file I/O, GUI events, network calls, background calculations (spell checker in word)

|  |  |  |
| --- | --- | --- |
| **Feature** | **Process** | **Thread** |
| Definition | Independent executing program | Smallest unit of execution inside a process |
| Memory | Each has its own memory space | Threads share memory of the process |
| Communication | Difficult (inter-process communication) | Easy(shared memory) |
| Overhead | High(more resources) | Low(Ligghtweight) |
| Example | Running MS Word & chrome as separate program | Two tabs running in the chrome  Spell checker in word..etc |

**Where Thread stored in Memory?**

* Each thread has its own stack (for method calls and local variables)
* But all the threads share heap memory of the process – meaning they can access and modify same objects

**Thread Lifecycle**

1. **New** – Thread is created but not yet started
2. **Runnable** (Ready) – Thread is ready to run but waiting for CPU
3. **Running** – Thread is currently executing
4. **Waiting/Blocked** – Thread is waiting indefinitely (or blocked) for another thread or some time
5. **Terminated** (dead) – Thread has finished execution

How you create thread?

Two ways:

1. **Implementing thread interface**
2. Extending thread class

**Race Condition**

A race condition occurs when:

* Two or more threads access shared data at the same time
* And at least one thread modifies it
* And result depend on the order of execution of threads

Synchronization (solution to race condition)

* Java provides **synchronization** to ensure only one thread at a time can access critical section.

**Every thread object has special property**

1. Lock – ~~1~~ 0
2. WaitListedSet {t1,t2,t3 }

**Inter-Thread communication**

Sometimes, one thread needs to wait for another thread to complete or send a signal.

Wait can only be called within **synchronized block**

Instead of busy-waiting (wasting CPU) time.

Mohit, Dhruvik, Thiru, Supriya

this.wait()

this.wait()

this.notifyAll()

Wait and notify

Wait() – tells the thread to go into waiting state

Notify() – wakes up one waiting thread

NotifyAll() – wakes up all waiting threads

Customer

1000 - balance

Deposit withdrawal

**29/06/2025**

**OOP – Concepts**

**Class and Objects**

Class – blueprint/Template

Class car {

Void drive() {

System.out.println(“”);

}

}

Car c = new Car();

c.drive()

**Encapsulation** – “Data Hiding and control”

Encapsulation means binding data and methods together and **restricting direct access to internal variables.**

Key points:

* Ensures security and control
* Improves maintainability

**Inheritance – “Code Reusability”**

Inheritance is the ability of one class to inherit fields and methods of another class

Key points:

* Promotes code reuse
* Supports Hierarchical and multilevel inheritance
* Base class == super class, derived class = subclass

**Polymorphism – “Many forms of one thing”**

Polymorphism means that a method or objects behaves differently in different context.

**Two type:**

1. **Compile-time Polymorphism (Method overloading)**

Same method name, different parameters in the same class

1. **Runtime Polymorphism (Method overriding)**

Same method name and signature in parent class and child class, behavior depends on the object type at runtime.

“Parent class can refer to the instance of the child class”

**Key points**

* Overloading – same class, compile time
* Overriding – Different class (Inheritance), runtime
* Achieves flexibility and extensibility

Dynamic Method dispatch is the mechanism by which a call to an overridden method is resolved at runtime, not compile time.

**Abstraction:**

Abstraction is the process of **hiding internal implementation** details and only **exposing essential features**.

Achieved using abstract class and interface.

* You define what needs to be done, not how
* Hides internal complexity
* Focus subclasses to implement logic

**Banking System**

Scenario:

You are building banking system with different types of accounts:

* SavingsAccount
* CurrentAccount
* FixedDepositAccount

Each account has a method called calculateInterest(int days) that behaves differently depending on the account type.

Parent class: BankAccount 🡪 Override the method in each subclass,

**What are access specifiers?**

Access specifiers in java are keywords used to set visibility levels for the classes, methods, variables and constructors.

They can control who can access a particular piece of code – whether it’s within the class, package, or across other packages.

1. **private**

Accessible only within the **same class**.

1. default

Accessible only **within the same package**.

Analogy: your local society notice board - accessible only to residents, not outsiders

1. protected

**Accessible**:

* within the same package
* In the subclasses (even in other package)

Analogy:

You share your family Netflix password only within family members (subclasses), even if they live in different cities(packages).

1. Public

Accessible from anywhere – any class, any package

Best practice:

* Use private for data hiding (encapsulation)
* Use public for class/Interface meant for external use
* Use protected when designing extensible classes (subclass access)
* Avoid using **default** unless you have package-scoped logic

**Methods:**

A method is block of code that performs a **specific task**, **can be reused**, , and **may return a result**.

**Constructors in java**

A constructor is a special method used to **initialize objects** when they are created. It has no return type (not even void) and **same name as the class**.

Types:

1. Default – No parameters, added by **compiler** if **none defined**.
2. No-Arg – User defined constructor with no parameters
3. Parameterized – Accepts parameters to initialize object values

If you do not call super() method (first line of the constructor) then compiler will add it.

Java.lang.Object – be the super class for all the classes that you create.

**What is copy constructor?**

A copy constructor is a special constructor that creates a new object by copying the fields of an existing object.

**28/06/2025**

What is Java?

* High level
* Object oriented
* Class based programming language
* Platform independent (**WORA** – Wrinte once, Run Anywhere)
* **Robust** and Secure

Code.java 🡪 .class 🡪 JRE

* Multithreading
* High performance with **JIT Compiler**
* Automatic Memory Management (Garbage collection)

Installing from OpenJDK

Configure JAVA\_HOME env variable, and add %JAVA\_HOME%\bin to your path variable

To verify : java –version (on command prompt)

JDK – Development kit (Compiler + JRE)

Public class Hello {

Public static void main(String[] args) {

System.out.println(“Hello world!”);

}

}

Hello.java 🡪 hello.class 🡪 JVM (resides under JRE)

Consider this bytecode as a universal language between your code and your machine.

**Data types**:

Type of the Data a variable can hold.

Strictly type language – means every variable must have a declared type.A diagram of data types

AI-generated content may be incorrect.

1 byte = 8 bits

1024 byts – 1 MB

1024 MB - 1 GB

1024 GB – 1 TB

**Unicode** is universal international standard character encoding system that **is capable of representing most of the world’s languages**.

* ASCII – for US
* ISO 8859-1 : for western europeon languages
* KOI-8 : for Russian
* GB 18030 and BIG-5 – for chenese and so on.

|  |  |  |
| --- | --- | --- |
| boolean | 1 bit (logical) | Only two numbers : true or false; **boolean flag=true** |
| char | 2 bytes | Single character (Unicode) , char c = ‘A’ |
| byte | 1 bytes (8 bit) | Small intergers (-128 to 127); byte b = 100 |
| Short | 2 bytes (16 bit) | Small integers (-215 to 215-1) ; short s = 32000; |
| Int | 4 bytes | Standard interger typs, int x = 10000; |
| Long | 8 bytes | Large interger types |
| Float | 4 bytes | Decimal numbers (single precision), float f= 10.5f; |
| Double | 8 bytes | Decimal numbers (Double precision), double d = 20.99; |

* Primitive data types are built-in in java
* Non Premitive are User defined types

**Type casting:**

* **Widening Type casting:** Converting a lower data type into higher one is called widening type casting. Or Implicit type conversion . it is automatically done by java. It is safe, because there is no chance of loosingdata.

**Byte🡪short🡪char🡪int🡪long🡪float🡪double**

* **Narrowing type casting:** Converting higher data types into lower one. Explicit conversion.

Double🡪float🡪long🡪int🡪char🡪short🡪byte

**Operators:**

1. Arithmatic operators (addition,substraction, multiplication, division, modulus)
2. **Relational (Comparision) Operators**:
   * + == 🡪 **5==5**
     + != 🡪 **5!=3**
     + > 🡪 5>3
     + < 🡪 3<5
     + >=
     + <=
3. **Logical operators**
   * + && 🡪Logical AND 🡪 true && false - false
     + !
4. **Assignment operators**
   * + **= 🡪** Assign value , a=10
     + **+= 🡪** Add and assign , a+=5
     + **-= 🡪** Subtract and assign, a-=3
     + \*=
     + /=
     + %=
5. **Unary Operator**

**++ 🡪 increment**

1. Bitwise operators

&,^,~,<<,>>,>>>

1. Ternary Operator

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Phase 1** | **JFSD: Data Structures and Algorithms** | | |
| 1 | 6/7/2025 |  | 4 | Foundations of Data structures and Algorithms (Time and space complexity), Arrays, Multidimentional array , |
| 2 | 6/8/2025 |  | 4 | LinkedList, Operations on LinkedList, Stacks, Queue |
| 3 | 6/14/2025 |  | 4 | Trees Binary, AVL tree implemenation , Graphs and its types (Graph traversal implementation |
| 4 | 6/15/2025 |  | 4 | HashMap Bubble sort and Selection sort implementation Insertion sort, merge sort, quick sort implementation |
| 5 | 6/21/2025 |  | 4 | Heap sort, count sort,  Linear search, Binary Search, Jump Search algorithm |
| 6 | 6/22/2025 |  | 4 | radix sort implementation Phase end project |

Phase 1:

22/062025

**Heap Sort:**

Heap Sort is ,

1. Build a **Max Heap** from the input array
2. Repeatedly Swaps the max (root) element with the last element
3. **Shrinks the heap** and happifies again to maintain max heap.

**What is Max Heap?**

A Max heap is a binary tree where,

* Every parent is greater than or equal to its children
* Its stored in array
  + Parent at i
  + Left child at 2i+1
  + Right Child at 2i+2

Example: [4,10,3,5,1]

Heapify index 1 (value 10)

[10,4,3,5,1]

[10,5,3,4,1]

[**1,5,3,4**,10]

[5,4,3,1,10]

[**1,4,3**,5,10]

[4,1,3,5,10]

[3,1,**4,5,10**]

[3,1,4,5,10]

[1,3,4,5,10]

**Count Sort:**

Counting sort is **a non-comparison-based sorting algorithm**.

Conditions:

* You must have non-negative integers
* The range of values(max-min) is not very large

arr= [4,2,2,8,3,3,1]

**Step 1**: Find max value

Max = 8

**Step 2: Create count array**

* Indexes from 0 to max
* Initialize all with 0 value

count = [0,0,0,0,0,0,0,0,0] // 9 elements

**Step 3: Count occurrences**

Loop through input array and update counts;

**count = [0,1,2,2,1,0,0,0,1]**

**Step 4: Reconstruct the sorted array**

Loop through count[], for each I, place I in result array [count[i] times.

Sorted: [1,2,2,3,3,4,8]

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**21-June-2025**

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**Merge Sort:**

Merge Sort is a classic **Divide and Conquer** algorithm that works by,

1. Dividing the array into halves until each subarray has only one element
2. Merging those sorted halves back together in order.

[2] [1]

[1,2]

[38] [27,43]

[27, 38, 43]

~~[27,~~**~~38~~**~~,43]~~ ~~[3~~**~~,~~**~~9,10~~,**82, 99,100,102**]

[3, 9 , 10, 27, 38, 43, 82]

**Quick Sort**

Quick Sort is also a Divide and Conquer algorithm.

Unlike merge sort, which divides array in half, quicksort works by selecting a **“pivot”** element, then partitions the array so:

* All elements < pivot go to the left
* All elements > pivot go to the right

Then recursively softs the left and right subarrays.

Binary Search:

Idea: Cut the sorted array in half repeatedly until element is found.

* **Use when the array is sorted**
* You want fast performance (much faster than linear search)

Target=11

[1,3,5,7,9,11]

16

[1,3**,**5,7,9,11,13,23,25,28,40,45,46,53,57,67,**68**,69,72,**89**,100]

i=1

while((i<n) && arr[i]<target) {

i=i\*2;

}

I=32

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**15-June-2025**

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**HashMap**

A hashMap is a key-value pair datastructure

Fast insertion, searching and deletion operations

Uses Hash Function to map keys to indices in array (buckets)

Name – Dhruvik

Name – Mohit

Age= 25

Characteristics:

* Key-Value pairs –{ name – Dhruvik, }
* No Duplicate keys allowed
* Allow Null Values as key and value
* Unordered – Doesn’t maintain insertion order
* Efficient lookup – O(1)

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**What is a Non-Linear Data Structure?**

Data elements are not arranged sequentially (not in straight line). Instead, they form a hierarchy or relationship between elements (like tree or graph)

* Elements can have multiple relations
* Not stored in contiguous memory locations
* Traversal is complex (Compared to array or linked list)

Examples:

* Tree
* Graph
* Heap

Why Non-Linear?

* To manage relationships (e.g. file system, organization charts)
* For efficient search and insert operations

**Tree**

A Tree is a hierarchical, non-linear datastructure made up of nodes

* Top node – root
* Each node (except root) has one parent
* Nodes may have children
* There are no cycle

A level 0

B C level 1

C E F

Use case?

* File system hierarchy
* XML/HTML DOM
* Databases (B-Tree, B+Tree)
* Routing algorithms in networks

Advantage

* Dynamic insertion/deletions
* Fast searching with ordered tree
* Mirrors natural hierarchical relationships

Terminologies:

* Node – Basic unit of tree with data
* Root Node – The topmost node
* Parent Node – A node that has children
* Child node – Node descended from another node
* Leaf node – A node with no children
* Internal Node – A node with atleast one child
* Degree – Number of children of a node
* Level – Distance from root (root – level 0)
* Height of Node – Longest path from node to a leaf
* Depth of node – Path length from root to that node

Types of tree:

* Binary Tree
* BST Tree
* AVL Tree
* B Tree

**Binary Tree**

* Each node has at most two children, (0,1,2)
* Foundation of more advanced trees like Binary Search Trees, AVL Trees, Heaps etc

Class TreeNode {

int data;

TreeNode left;

TreeNode right;

}

**Types of Binary Trees**

1. **Full Binary Tree –** Every node has 0 or 2 children
2. **Perfect Binary Tree** 
   1. **All interior nodes have two children**
   2. **All leaves at the same level**

**1**

**2 3**

**4 5 6 7**

1. **Complete Binary Tree**

All levels are fully filled except last, and the last level is filled left to right.

1. **Skewed Binary Tree**

All nodes have only one child (either left or right)

**Binary Search Tree**

A Binary Search tree is binary tree with a special properties

* All nodes in the left subtree have values less than node’s value
* All the nodes in the right subtree have values greater than node’s value
* This rule applies recursively to all nodes

**AVL Tree**

An AVL Tree is self-balancing Binary Search Tree (BST) where the difference in heights between left and right subtree of any node is at most 1.

The height difference is called Balance Factor –

Balance Factor = Height(left\_subtree) – height(right\_subtree)

Valid values of BF - -1,0,1

How ?

LL – Left Left - Inserted into left of left

RR – Right Right

LR – Left Right

RL – Right Left

**B- Tree**

A B-Tree is a self-balancing search tree that is optimized for systems that read and write large blocks of data like datasets and file systems

Generalization of BST but allows a node to have more than two childrens

Fundamentals:

1. Multi-way tree
   * A B-Tree of order m, can have upto m children per node
   * Each node can hold multiple keys (upto m-1 keys) arranged in **sorted order**
2. Balanced Tree
   * The B-Tree is always balanced – all leafs nodes are at the same level
   * It keeps height small for fast access.
3. Sorted Keys
   * Keys in each node are kept in sorted order
   * Search is done using binary search within the node
4. Broad and shallow

**Tree Traversals**

1. Depth First Traversal (DFT)
   1. Inorder (Left -> root -> right)
   2. Preorder (Root -> left -> right)
   3. Postorder (Left -> right -> root)
2. Breadth First Traversal (BFT)

**Graph**

Graph is a non linear datastructure consisting of:

Vertices (or nodes) – Points

Edge (or arcs) – connection between Vertices

Real-world examples:

* Social network (people – nodes, relationships – edge)
* Maps (Cities – nodes, roads – edge)
* Internet (Web pages = nodes, hyperlinks- edge)

Treee and Graph?

|  |  |  |
| --- | --- | --- |
| Feature | Tree | Graph |
| Structure | Hierarchical | Network-like |
| Cycles | No cycles | May have cycle |
| Parent/Child | Defined | No such concept |
| Connectivity | One path between nodes | Multiple paths may exist |
| Edge Count | n-1 edges | Can have any number of edges |
| Root | Always has one root | No root required |
| Direction | Usually one direction | Can be directed/undirected |

|  |  |  |
| --- | --- | --- |
| Term | Meaning | |
| Vertex(Node) | | Fundamental unit of graph |
| Edge(Arc) | | Connection between two nodes |
| Adjacency | | Two nodes are adjacent if they are connected by an edge |
| Path | | A sequence of vertices connected by edges |
| Degree | | Number of edges connected to a node |
| Cycle | | A path that starts and ends at the same vertex |
|  | |  |

**Types of graphs**

1. **Based on Structure**
   1. Finite Graph
      1. Has finite number of nodes and edges
   2. Infinite Graph
      1. Theoretically contains infinite nodes/edges
      2. Not practical in memory, used in theoretical math
   3. Trivial Graph
      1. Has only one vertex and **no edges**
   4. Null Graph
      1. Contains n vertices and no edges
   5. Simple Graph
      1. No Self-loops or multiple edges
   6. Multi Graph
      1. Has multiple edges (parallel edges) between two nodes
   7. Psuedo Graph
      1. Contains self loops (an edge from one node to itself)
2. **Based on Connectivity**
   1. Connected Graph
      1. There is a path between every pair of vertices (e.g. social network where everyone is somehow connected)
   2. Disconnected graph
      1. Some Nodes are isolated (no connection to rest)
3. **Based on Direction and Weight**
   1. Directed Graph (Digraph)
      * Edges have direction(A -> B is not B-> A)
   2. Undirected Graph
      * Edges do not have direction (A- B)
   3. Weighted Graph
      * Each edge has weight or cost (distance, time)
   4. Unweighted Graph
      * All edges are treated equally
4. **Based on cycles**
   1. Cyclic Graph
      * Contains at least one cycle (e.g. A->B->C->A)
   2. Acyclic Graph
      * No cycles present
   3. Directed Acyclic Graph (DAG)
      * Directed and acyclic
      * Scheduling, Orchastrator, Building systems
5. **Others**
   1. Complete Graph
      * Every node is connected to every other node
   2. Regular Graph
      * All vertices have same degree
   3. Sub Graph
      * A subset of the original graph’s vertices and edges

**Graph Representations:**

**Adjacency matrix**

2D matrix – adj[i][j] = 1, if there’s any edge from vertex i to j

Space: O(V2)

A B C

A-B B-C

|  |  |  |  |
| --- | --- | --- | --- |
|  | **A** | **B** | **C** |
| **A** | **0** | **1** | **0** |
| **B** | **1** | **0** | **1** |
| **C** | **0** | **1** | **0** |

**Pros:**

Fast edge lookup : O(1)

**Cons:**

Space inefficient for sparse graphs

**B. Ajdacency List**

- Each vertex stores list of adjacent vertices

A -> B

B ->A, C

C -> B

Pros:

* Efficient for spase graphs
* Easy to integrate neighbors

Cons:

* Slower edge lookup

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**08-June-2025**

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**Assignment**:

For given array return transpose array.

Transpose Array

1 2 3

4 5 6

1. 4
2. 5
3. 6

3 X2 result

Multi-Dimensional Arrays - Two Dimensional Arrays

[2,3,4,5]

[ [1,2], [3,4] , [5,6] ] -2D array

1 2

3 4

5 6

3 X2 array

Int[][] arr = new int[3][3];

Int[][] arr2 = {{1,2}, {3,4}, {5,6}}

1 2 5 6

3 4 7 8

6 8

10 12

**Linked List**

A linked list is a linear data structure where elements are stored in nodes.

Each node has data and a pointer to the next node.

Why Linked List?

* Dynamic size
* Efficient Insertion and Deletion operations

Types of linked lists:

* Singly Linked List - Each node points to the next
* Doubly Linked List - Each node points to the both next and previous nodes
* Circular Linked List - Last node points to the first node

1,2,3

1,2,3,4

|  |  |  |
| --- | --- | --- |
| Feature | Array | LinkedList |
| Size | Fixed (Static) | Dynamic (Grows/s |
| Insert/Delete | Costly (shift elements) | Fast (change pointers) |
| Access time | Fast (random access) | Slower (sequential access) |
| Memory Allocation | Contiguous | Non-Contigous |

**Stack:**

A stack is a linear data structure that follows the LIFO (Last In, First Out) principle.

* You can add (push) and remove (pop) elements from the top of the stack
* Pile of plates 🡪

**Queue:**

* A queue is linear data structure that follow the FIFO (First In, First Out) Principle
  + Elements are added at the rear (enqueue) and removed from the front(dequeue).
  + Think of it as a line at a ticket counter.

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**07-June-2025**

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Datastructure –

Way of organizing and storing data so that it can be accessed and modified efficiently.

**Commons operations in Data structures:**

* Insertion
* Deletion
* Searching
* Traversal
* Sorting

**Examples:**

* **Array** – Fixed size collection of elements of the same type
* **Linked List** – Collection of nodes connected by references
* **Stacks** – LIFO (Last In First Out) data structure
* **Queues** – FIFO (First in First Out) data structure
* **Trees** – Hierarchical data structure
* **Graphs**: Set of nodes connected by edges

**DataStructures vs Data Types**

**Data Type:** Type of variable

Int, float

**Why need for data structure?**

* Efficient data storage and access
* Reduce Time Complexity of operations
* Better organization for complex data
* Essential in system design and scalable applications

**“**Alice”, 23, BEIT, BOB,24, MCA

[

{name: Alice, age: 23, course: BEIT},

{name: Bob, age: 24, course: MCA}

]

Classification of Data structures:

**Linear Data structures**:

Arrays, Linked Lists, Stack, Queues

[1] 🡪 [2] 🡪 [3] 🡪 [4]

**Non-Linear Data structures:**

Trees, Graphs

1

**Algo Characteristics:**

* Takes input
* Gives Output
* Finiteness
* Effectiveness

**Assignment**:

1. Write a program to find the sum of all elements in a integer array

[2,4,6,8] 🡪 **output**: 20

1. Write program to reverse the elements of an array:

[1,2,3,4] 🡪 **Output**: [4,3,2,1]

1. Find maximum and Minimum in an array

Input: [5,8,3,1,9] 🡪 **Output** : Max: 9, Min: 1

1. Count even and Odd numbers in an array

**Input**: [2,3,5,6,8] 🡪 **Output**: Even : 3, Odd: 2

1. Print all elements at even indexes:

**Input**: [10,20,30,40,50] 🡪 **Output**: 10 30 50

**Time Complexity**

Amount of time taken by algorithm to run.

Time and Space complexity can define effectiveness of an algorithm.

**Big O Notation** – mathematical way to describe the time complexity of an algorithm in terms of input size n. It tells you how the performance of your algorithm scales as the input grows.

Compare different algorithms

**Different types of Time Complexities:**

1. Constant Time – O(1) - Time doesn’t grow with input size
2. Linear Time – O(n) - Grows proportionally with the input size
3. Logarithmic Time : O(log n) - Cuts input in half each time
4. Quadratic Time: O(n^2) - Slower for large input
5. Cubic Time – O(n^3) -
6. Exponential Time - O(2^n) - Very slow, doubles time each step
7. Factorial Time – O(n!) - Extremely slow even for small n

What can cause time in function?

1. Operations (+,-….)
2. Comparisons (>,<,==)
3. Looping (for, while)

Rules:

1. Always consider worst case
2. Remove constants
3. Remove non dominant terms

Iteration: x

1. x
2. x/2
3. x/4
4. x/8

….

K x/2^k

2^k = x

K = log2(x)

**Space Complexity**

Space complexity is the total memory used by an algorithm as a function of input size n.

It includes:

* Memory used by input data
* Memory used by variables
* Memory used by recursion stack or function calls
* Memory used by auxiliary data structures (like arrays, hashmaps exc)