Computer systems can be divided into four components: Hardware, Operating system, Application programs, Users

What is an Operating System (OS)? - Software that serves as the foundation for a computer system, providing essential functions and managing hardware and software resources.

OS acts as an intermediary between computer hardware and user applications.

The primary purpose of an operating system is to enable the execution of user programs while ensuring the efficient and secure allocation of system resources, such as **memory, processing power, storage, and input/output devices.**

Components of OS: 1. Kernel provides essential services and manages the system's resources; it acts as a bridge between the hardware and software layers of the system. **2. File System:** The file system component manages the organization, storage, retrieval, and access of files on secondary storage devices such as hard drives or solid-state drives. It provides a hierarchical

structure for organizing files and includes features like file permissions, directory management, and file metadata. **3. Device Drivers:** Device drivers are software modules that facilitate communication between the operating system and hardware devices such as printers, keyboards, monitors, and network interfaces.

They enable the operating system to control and interact with these devices. **4. User Interface:** The user interface component provides a means for users to interact with the operating system. It can take the form of a command-line interface (CLI), where users enter text commands, or a graphical user interface (GUI), which presents a visual environment with icons, windows, and menus. **5. Networking:** Networking components enable the operating system to support network connectivity and communication. They include protocols, drivers, and services that allow the system to connect to networks, access the internet, and transfer data. **6. Security:** The security component ensures the protection of the system and its resources against unauthorized access, threats, and vulnerabilities. It includes features such as user authentication, access

control, encryption, and firewall capabilities. **7. File and Data Management:** This component includes utilities and services for managing files, directories, and data on the system. It handles tasks like file organization, recovery, and data integrity.

8. System Libraries: System libraries are collections of precompiled code that provide common functions and services to applications. They allow programmers to leverage existing functionality without having to develop everything from scratch

Key Features of an OS: Process management, Memory management, File system management, Device management, User interface

Big Pic of OS: User -> List of Services -> System Calls -> Kernel -> Interrupt -> CPU -> Processes -> Thread

Storage: Main memory – only large storage media that the CPU can access directly -> Random access, Typically volatile, Typically random-access memory in the form of Dynamic Random-access Memory

Secondary storage – extension of main memory that provides large nonvolatile storage capacity

Hard Disk Drives (HDD) – rigid metal or glass platters covered with magnetic recording material. -> Disk surface is logically divided into tracks, which are subdivided into sectors The disk controller determines the logical interaction between the device and the computer

Storage systems organized in hierarchy: Speed, Cost, Volatility

Caching – copying information into faster storage system; main memory can be viewed as a cache for secondary storage

Device Driver for each device controller to manage I/O, -> Provides uniform interface between controller and

Multiprocessors: Also known as parallel systems, tightly coupled systems

Advantages include: 1. Increased throughput 2. Economy of scale 3. Increased reliability – graceful degradation or fault tolerance

Two types: 1. Asymmetric Multiprocessing 2. Symmetric Multiprocessing

Clustered Systems: 1. Asymmetric clustering has one machine in hot-standby mode **2. Symmetric clustering** has multiple nodes running applications, monitoring each other

User Mode: The system is in user mode when the operating system is running a user application such as handling a text editor.

The transition from user mode to kernel mode occurs when the application requests the help of the operating system or an interrupt or a system call occurs.

The mode bit is set to 1 in the user mode. It is changed from 1 to 0 when switching from user mode to kernel mode.

Kernel Mode: The system starts in kernel mode when it boots and after the operating system is loaded, it executes applications in user mode.

There are some privileged instructions that can only be executed in kernel mode.

These are interrupt instructions, input output management etc. If the privileged instructions are executed in user mode, it is illegal, and a trap is generated.

The mode bit is set to 0 in the kernel mode. It is changed from 0 to 1 when switching from kernel mode to user mode.

A process is a program in execution. It is a unit of work within the system. Program is a passive entity, process is an active entity

Process Management: 1. Single-threaded process has one program counter specifying location of next instruction to execute

- Process executes instructions sequentially, one at a time, until completion

2. Multi-threaded process has one program counter per thread

Typically system has many processes, some user, some operating system running concurrently on one or more CPUs

Memory Management: To execute a program, all (or part) of the instructions must be in memory. Memory management determines what is in memory and when. Optimizing CPU utilization and computer response to users.

File-system Management: OS provides a uniform, logical view of information storage. Files are usually organized into directories. Access control determines who can access what. OS activities include

Creating and deleting files and directories, Primitives to manipulate files and directories, Mapping files onto secondary storage, Backup files onto stable (non-volatile) storage media

Mass-Storage Management: Usually, disks are used to store data that does not fit in the main memory. Proper management is of central importance. The entire speed of computer operation hinges on

disk subsystem and its algorithms. OS activities include Mounting and unmounting, Free-space management, Storage allocation, Disk scheduling, Partitioning, Protection

Caching: Important principle, performed at many levels in a computer. Information in use copied from slower to faster storage temporarily.

Faster storage (cache) checked first to determine if information is there.

Types of Cache Memory: L1 cache, or primary cache, is extremely fast but small, usually embedded in the processor. L2 cache is often more capacious than L1, may be embedded on the CPU or on a separate chip. L3 cache is specialized memory developed to improve the performance of L1 and L2.

- With multicore processors, each core can have dedicated L1 and L2 caches but share an L3 cache.

Transition from User to Kernel Mode: -> Timer to prevent infinite loop / process hogging resources. ->Timer is set to interrupt the computer after some time. -> Keep a counter that is decremented by the physical clock. -> Operating system set the counter (privileged instruction). -> When counter zero generate an interrupt ->Set up before scheduling process to regain control or terminate program that exceeds allotted time.

Debugging is finding and fixing errors, or bugs.

Failure of an application can generate **core dump** file capturing memory of the process

Operating system failure can generate **crash dump** file containing kernel memory

Profiling is periodic sampling of instruction pointers to look for statistical trends.

Kernighan's Law: "Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug

UX - User Experience, UI - User Interface

Thread: is the segment of a process means a process can have multiple threads and these multiple threads are contained within a process.

• A thread has **3 states: running, ready, and blocked.**

• Thread takes less time to terminate as compared to process

A thread is a **path of execution within a process**. A process can contain **multiple threads.**

Why Multithreading? A thread is also known as **lightweight process**

Process vs Thread? The primary difference is that threads within the same process run in a shared memory space, while processes run in separate memory spaces.

Threads are not independent of one another like processes are.

Advantages of Thread over Process

1. Responsiveness: If the process is divided into multiple threads, if one thread completes its execution, then its output can be immediately returned.

2. Faster context switch: Context switch time between threads is lower compared to process context switch. Process context switching requires more overhead from the CPU.

3. Effective utilization of a multiprocessor system: If we have multiple threads in a single process, then we can schedule multiple threads on multiple processors. This will make process execution faster.

4. Resource sharing: Resources like code, data, and files can be shared among all threads within a process. Note: stack and registers can't be shared among the threads. Each thread has its own stack and registers.
Types of Threads: There are two types of threads. 1) User Level Thread 2) Kernel Level Thread
Process means any program is in execution**. Process control block (PCB)** controls the operation of any process. Process execution must progress in **sequential fashion**
Process **Concept**: Program is a **passive** entity stored on disk (executable file); the **process is active**. Program becomes a process when an executable file is loaded into memory. Execution of a program started via GUI mouse clicks, command line entry of its name, etc One program can be several processes. Consider multiple users executing the same program.
Process **State**: As a process executes, it changes state **1) New**: The process is being created **2) Running:** Instructions are being executed **3) Waiting:** The process is waiting for some event to Occur **4) Ready:** The process is waiting to be assigned to a Processor **5) Terminated:** The process has finished execution.
Multithreading Models: Many-to-One, One-to-One, Many-to-Many

S.NO	PROCESS	THREAD
1.	Process means any program is in execution.	Thread means segment of a process.
2.	Process takes more time to terminate.	Thread takes less time to terminate.
3.	It takes more time for creation.	It takes less time for creation.
4.	It also takes more time for context switching.	It takes less time for context switching.
5.	Process is less efficient in term of communication.	Thread is more efficient in term of communication.
6.	Process consume more resources.	Thread consume less resources.
7.	Process is isolated.	Threads share memory.

Ppt9: AI in OS:

Automated Code Generation, Dynamic Resource Allocation, Power Management, Fault Tolerance and Self-Healing,User Interface Optimization, Security and Malware Detection, Performance Optimization, Virtual Assistants and Intelligent Agents, Predictive Maintenance, Automated Testing and Verification
Ppt10: Trends in OS: Containerization, Serverless Computing, Unikernel Operating Systems, Immutable Operating Systems, Secure Boot and Trusted Execution Environments, Energy-Efficient Operating Systems, Real-Time Operating Systems, Microkernel Architectures, Adaptive Operating Systems, Human-Centric Operating Systems

VUI - Voice USer Interface
GUI - Graphical User Interface
CLI - Command line Interface
ISA - Instruction Set Architecture
HDD - Dynamic Random-access Memory
DRAM - Hard Disk Drives
NVM - Hard Disk Drives
HPC - High Performance Computing
DLM - distributed lock manage
Linker: combines relocatable object files into single binary executable files.
DLL: dynamically linked libraries
LAN- Local Area Network
WAN- Wide Area Network
MAN- Metropolitan Area Network
PAN- Personal Area Network
SAN- Storage Area Network
UI - User Interface
UX - User Experience
API - Application Program Interface

Protection – any mechanism for controlling access of processes or users to resources defined by the OS
Security – defense of the system against internal and external attacks
4 types of interfaces: command-line, graphical, batch, touch-screen

Instruction set – list of commands the CPU can understand and carry out
Main difference between the two design types is the number of **different instructions the chip can process.**

CISC and RISC CPUs differ in the following ways: 1) Complex versus simple instructions 2) Clock cycles 3) Pipelining: The ability of the CPU to perform more than one task on a single clock cycle 4) Hardware versus microcode 5) Compiler
The speed of a CPU defines how fast it can perform operations. Most obvious indicator is the **internal clock speed**
Cache There are different levels of cache
Level 1 (L1) cache is the fastest and usually runs at the same speed as the CPU
Level 2 (L2) cache is slower but much larger
Level 3 (L3) cache, until the last several years, was not part of the CPU chip, but part of motherboard
Level 4 (L4) cache will usually be found on motherboard (if it exists)
Cache controller – predicts what data will be needed and makes the data available in cache before it is needed
CPU Scheduling – determines which process to start given the multiple processes waiting to run
Control bus to keep the CPU informed about the status of resources and devices connected to the computer
Address Bus – internal communications pathway that specifies the source and target addresses for memory reads and writes
The data bus allows computer components, such as CPU, display adapter, and main memory, to share information
Interrupt request (IRQ) – a request to the processor to "interrupt" whatever it is doing to take care of a process, which in turn might be interrupted by another process.
processors include the Motorola, PowerPC, the SPARC, and the Alpha
three main cloud service models: **IaaS (infrastructure as a service), PaaS (platform as a service), and SaaS (software as a service)**.
XaaS stands for "Anything as a Service"
Summary of **OS Flow:**

1. **User interact**s with the system via services.
2. **System calls** request OS functionalities.
3. The **kernel** manages resources.
4. **Interrupts** handle system events.
5. The **CPU** executes processes.
6. **Processes** contain multiple **threads** for parallel execution.

List of Services: File Management – Opening, closing, reading, and writing files., **Process Management** – Running applications and allocating CPU resources., **Device Management** – Handling input/output devices like keyboards, printers, and storage.**Memory Management**
System calls are the interface between user applications and the OS kernel. When a program needs to perform an action requiring OS intervention, it makes a system call.
The **kernel** is the core component of the OS, responsible for managing system resources like CPU, memory, and I/O devices.
Nova is the primary computing engine.
Swift is a storage system for objects and files
Cinder is a block storage component,
Neutron provides the networking capability for OpenStack.
Horizon is the dashboard behind OpenStack.
Keystone provides identity services for OpenStack.
Glance provides image services to OpenStack.
Ceilometer provides telemetry services Heat is the orchestration component of OpenStack,

#TEST2

1. **List types of Threads?** User level thread, Kernel level thread
2. **List 3 definitions of Threads?** a) A thread is a path of execution within a process. b) A thread is a lightweight process. c) Thread is a segment of process.
3. **States of Threads?** Running, Ready, Blocked
4. **Define Process?** A program in execution
5. **List States of Process?** States of process: New, Running, Waiting, Ready, Terminated
6. **List types of Pipes?** Ordinary Pipes, Named pipes
7. **Big Pic of OS:** User -> List of Services -> System Calls -> Kernel -> Interrupt -> CPU -> Processes -> Thread
8. **3 advantages of Threads?** Resource sharing, Responsiveness, Effective Utilization
9. **types of CPU Buses ?** Address Bus, Control Bus, Data Bus
10. **List elements of the CPU?** Control Unit, Arithmetic Logic Unit, Register, System Bus
11. **Define CISC and RISC?** CISC- Complex Instruction Set Computing, RISC- Reduced Instruction Set Computing
12. **4 hardware classifications of CPU?** Speed, Cache, Address bus, Data bus, Control bus, CPU scheduling
13. **3 components of OpenStack:** Compute, Storage, Image Service
14. **4 Core Components of OpenStack?** Nova, Swift, Cinder, Neutron, Keystone, horizon
15. **OpenStack?** OpenStack is an open source infrastructure as a service initiative for creating and managing large groups of virtual private servers in a cloud computing environment.

#TEST1

1. OS - Operating System is system software that manages all computer resources.
2. HPC - High Performance Computing
3. Asymmetric Multiprocessing: Each processor performs a specific/particular task.
4. Symmetric Multiprocessing: Each processor performs all tasks.
5. RAM: 1) RAM is Volatile memory, 2) Access speed of RAM is faster, 3) High Storage Capacity
ROM: 1) ROM is Non-volatile memory, 2) Access speed of ROM is slower than the RAM, 3) Low Storage Capacity
6. Interrupt is a hardware mechanism in which the device notices that it requires its attention.
7. Polling is a protocol in which the CPU steadily checks whether the device needs attention.
8. Interrupt Advantages: 1) It Increases the efficiency of CPU 2) It decreases the waiting time of CPU
9. Interrupt Disadvantage: Workload on CPU increases due to handling of the interrupt.
10. Interrupt: 1) An interrupt is not a protocol; it's a hardware mechanism. 2) In interrupt, the device is serviced by interrupt handler. 3) An Interrupt can take place at any time. **Polling:** 1) Polling isn't a hardware mechanism, it's a protocol. 2) In polling, the device is serviced by CPU. 3) Whereas CPU steadily polls the device at regular intervals.
12. components of the von Neumann system:1) Memory, 2) Control Unit, 3) Arithmetic Logic Unit, 4) Processor, 5) Accumulator, 6) Input/Output Devices
13. Computer architecture is the logical design of a computer while **computer organizaion** is the physical structure of the system.
14. Two Modes of OS: 1) User Mode, 2) Kernel Mode
15. A process is a program in execution.

Quiz:

Types of cloud computing: public, private, hybrid
3 services of cloud computing: infrastructure, software, platform
5 components of OS: process management, memory management, file system management, Kernel, security management.
Types of OS: Normal, Distributed, Multiprocessor, Database, Real-time
Design Issues in OS: Transparency, scalability, flexibility, Reliability, Performance , Security, Naming
Examples of system services: Error handling and I/O operations.
Examples of system calls: File management and device management
Operating system failure can generate **crash dump** file containing kernel memory
Failure of an application can generate **core dump** file capturing memory of the process

MID:

Operating System is system software that manages all computer resources.

Components of Computer System:1) Memory,2) Control Unit, 3) Arithmetic Logic Unit,4) Processor,5) Accumulator,6) Input/Output Devices

System Call: A system call is the programmatic way in which a computer program requests a service from the kernel of the operating system it is executed

4 Design Issues: Reliability, Performance , Security, Naming, Concurrency, Resource Management

Two examples of Primary Storage: Registers, Random Access Memory (RAM) and Cache Memory

Buffering- storing data temporarily while it is being transferred.

Caching- Storing parts of data in faster storage for performance.

Spooling- The overlapping of output of one job with input of other jobs.

two main types of containers: Docker, Kubernetes

most used **programming language in OS: C, C++**

3 services provided by OS: File Management, Process Management, Device Management,Memory Management

7 layers of OSI: Application, Presentation, Session, Transport, Network, Data link, Physical

FINAL:

1. **Interrupt** is a hardware mechanism in which the device notices that it requires its attention.
2. **Polling** is a protocol in which the CPU steadily checks whether the device needs attention.
3. **Big Pic of OS:** User -> List of Services -> System Calls -> Kernel -> Interrupt -> CPU -> Processes -> Thread
4. **ABI** : Application Binary Interface
5. **2 types of Threads:** User level thread, Kernel level thread
6. **3 definitions of Threads?** a) A thread is a path of execution within a process. b) A thread is a lightweight process. c) Thread is a segment of process.
7. **A process** is a program in execution.
8. **2 types of Pipes:** Ordinary Pipes, Named pipes
9. Policy: What will be done? Mechanism: How to do it?

Mechanisms determine how to do something, **policies** decide what will be done

10. **types of CPU Buses:** Address Bus, Control Bus, Data Bus
11. **4 hardware classifications of CPU:** Speed, Cache, Address bus, Data bus, Control bus, CPU scheduling, Design type
12. **OpenStack** is an open source infrastructure as a service(IaaS) initiative for creating and managing large groups of virtual private servers in a cloud computing environment.
13. **3 components of OpenStack:** Compute, Storage, Image Service
14. **States of Threads:** Running, Ready, Blocked
15. **States of process:** New, Running, Waiting, Ready, Terminated
16. AI help OS: mentioned above in ppt9
17. **components/elements of the CPU:** Control Unit, Arithmetic Logic Unit, Register, System Bus
18. Trends in OS: mentioned above in ppt10
19. **VUI** - Voice User Interface
20. Examples of resources used by OS: CPU, memory(RAM), I/O devices, Processes, threads