Section 3: Computer Organization and Architecture – Subtopics for GATE

1. Machine Instructions and Addressing Modes

- Instruction format (fields: opcode, operand, addressing)
- Types of instructions:
    - Data movement (load/store, move, push/pop)
    - Arithmetic and logical
    - Control flow (branch, jump, call, return)
    - Input/Output instructions
- Addressing modes:
    - Immediate
    - Direct
    - Indirect
    - Register
    - Register Indirect
    - Displacement / Base-index
    - Relative
    - Indexed
- Effective Address (EA) calculation examples
- Instruction cycle (fetch, decode, execute)

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2. ALU, Datapath and Control Unit

- **ALU (Arithmetic Logic Unit):**
    - Functions (addition, subtraction, logic ops, shift ops)
    - Status flags (Zero, Carry, Sign, Overflow)
- **Datapath:**
    - Single-cycle vs multi-cycle datapath
    - Instruction execution steps
    - Role of registers (IR, PC, MAR, MDR, ACC)
- **Control Unit:**
    - Hardwired control
    - Micro-programmed control (horizontal vs vertical microcode)

- Control signals and sequencing

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3. Instruction Pipelining

- Concept of pipelining (k-stage pipeline, speedup formula)
- Phases of instruction execution in pipeline
- Pipeline hazards:
  - **Structural hazards** (resource conflicts)
  - **Data hazards** (RAW, WAR, WAW)
  - **Control hazards** (branch hazards)
- Hazard resolution techniques:
  - Data forwarding / bypassing
  - Pipeline stalling (bubbles)
  - Branch prediction (static & dynamic)
  - Delayed branching

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4. Memory Hierarchy

- **Cache memory:**
  - Need for cache, principles of locality (temporal & spatial)
  - Cache mapping techniques:
    - Direct mapped
    - Fully associative
    - Set associative
  - Cache replacement policies:
    - LRU, FIFO, Random
  - Cache write policies:
    - Write-through, Write-back, Write-around
  - Cache performance (hit ratio, miss penalty, AMAT formula)
- **Main Memory:**
  - DRAM vs SRAM
  - Memory interleaving
  - Memory bandwidth

- **Secondary Storage:**
    - Magnetic disks (seek time, rotational latency, transfer time)
    - SSD basics
    - Disk scheduling algorithms (FCFS, SSTF, SCAN, C-SCAN, LOOK, C-LOOK)

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5. I/O Interface

- **Modes of I/O transfer:**
    - Programmed I/O
    - Interrupt-driven I/O
    - Direct Memory Access (DMA)
- **Interrupts:**
    - Types (maskable, non-maskable, vectored, non-vectored)
    - Interrupt handling sequence
    - Interrupt priority
- **DMA:**
    - Working principle
    - Cycle stealing
    - Burst mode vs block transfer
    - DMA vs Interrupt I/O vs Programmed I/O
- I/O mapped vs Memory mapped I/O