Amirkabir University of Technology
(Tehran Polytechnic)

Operating Systems

Scheduling Algorithms

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Classes

Saturday	Monday	Saturday	Monday
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🟩	🟩	🟩	🟩
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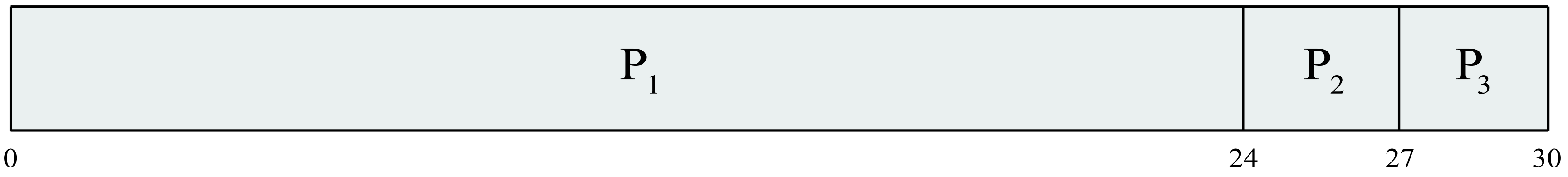
First-Come, First-Served

First- Come, First-Served (FCFS) Scheduling

Process	Burst Time
P_1	24
P_2	3
P_3	3

- Suppose that the processes arrive in the order: P_1 , P_2 , P_3
- The Gantt Chart for the schedule is:



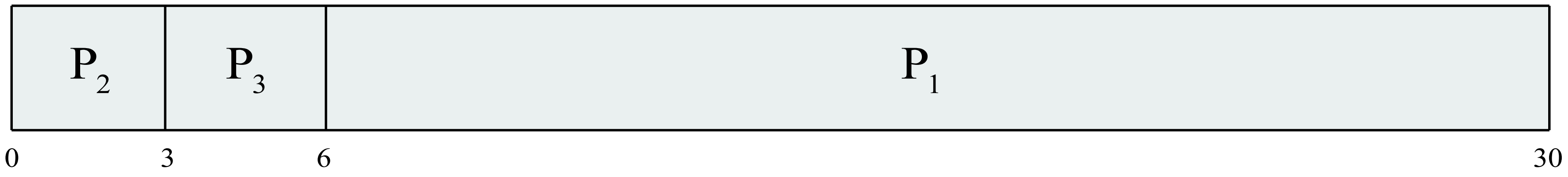
- Waiting time for P_1 = 0; P_2 = 24; P_3 = 27
- Average waiting time: (0 + 24 + 27)/3 = 17

FCFS Scheduling (Cont.)

Suppose that the processes arrive in the order:

P_2 , P_3 , P_1

- The Gantt chart for the schedule is:



- Waiting time for $P_1 = 6$; $P_2 = 0$; $P_3 = 3$
- Average waiting time: $(6 + 0 + 3)/3 = 3$
- **Much better than previous case**

FCFS Scheduling and Convoy effect

- **Short process behind long process.**
  - Consider one CPU-bound and many I/O-bound processes.

- **What is the important side-effect?**

FCFS Scheduling and Convoy Effect (Cont.)

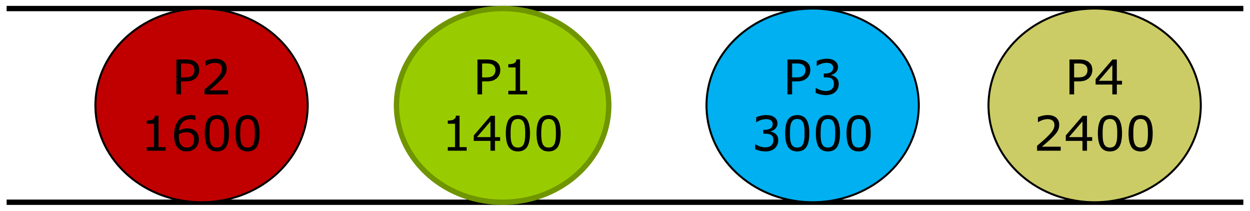
- **Short process behind long process.**
  - Consider one CPU-bound and many I/O-bound processes.

- What is the side-effect?
  - Results in **lower CPU and device utilization** than might be possible if the shorter **processes were allowed to go first.**

Shortest-Job-First

Shortest-Job-First (SJF) Scheduling

- **Associate** with each process the length of its **next CPU burst**.
  - Use these lengths to schedule the process with the shortest time.



Ready Queue

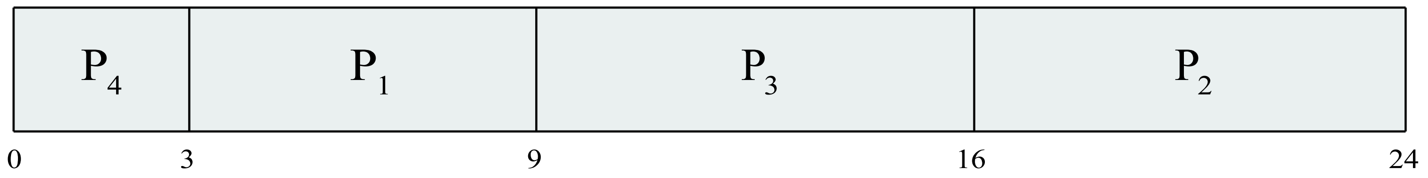
Shortest-Job-First (SJF) Scheduling (cont.)

- **SJF is optimal**
  - **Gives minimum average waiting time** for a given set of processes.
- Preemptive version called **shortest-remaining-time-first**
- **The difficulty is knowing the length of the next CPU request**
  - Could ask the user
  - Estimate (we do not cover this in the class and the exams)

Example of SJF

Process	Burst Time
P_1	6
P_2	8
P_3	7
P_4	3

- SJF scheduling chart



- Average waiting time = (3 + 16 + 9 + 0) / 4 = 7

Round-Robin

Round Robin (RR)

- **Each process gets a small unit of CPU time (time quantum q)**
  - Usually 10-100 milliseconds.
  - After this time has elapsed, the process is preempted and added to the end of the ready queue.
- **If there are n processes in the ready queue and the time quantum is q:**
  - Each process gets 1/n of the CPU time in chunks of at most *q* time units at once.
  - No process waits more than *(n-1)q* time units.

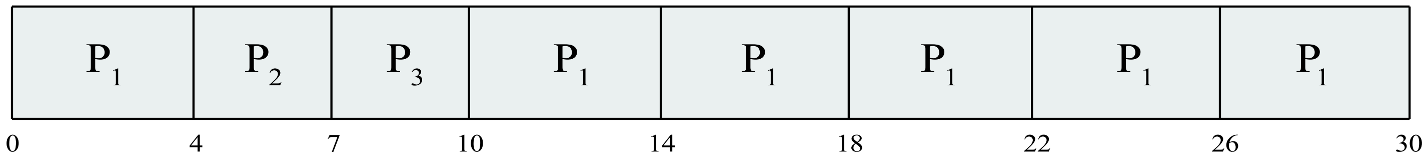
Round Robin (RR) (cont.)

- Timer *interrupts* every quantum to schedule next process
- Performance
  - *q* large $\Rightarrow$ FIFO
  - *q* small $\Rightarrow$ *q* must be large with respect to context switch, otherwise overhead is too high

Example of RR with Time Quantum = 4

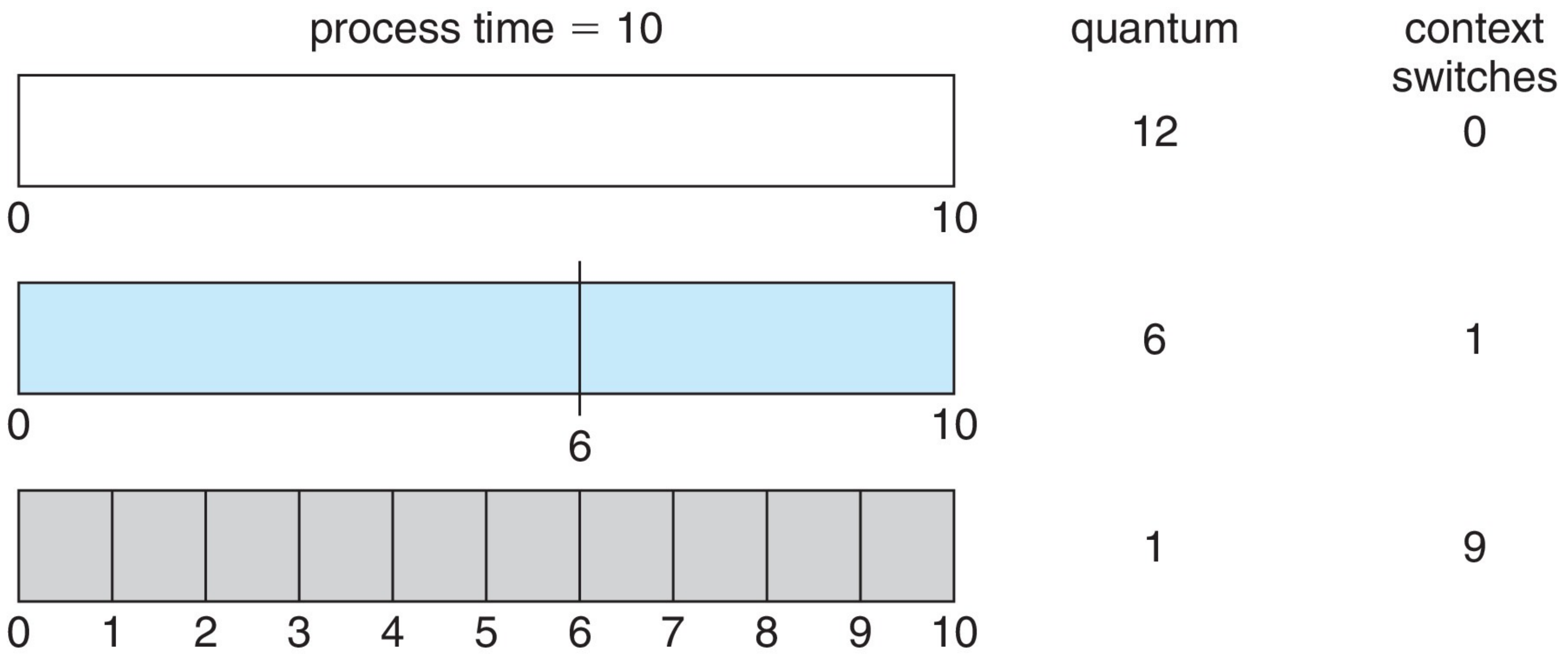
Process	Burst Time
P_1	24
P_2	3
P_3	3

- The Gantt chart is:

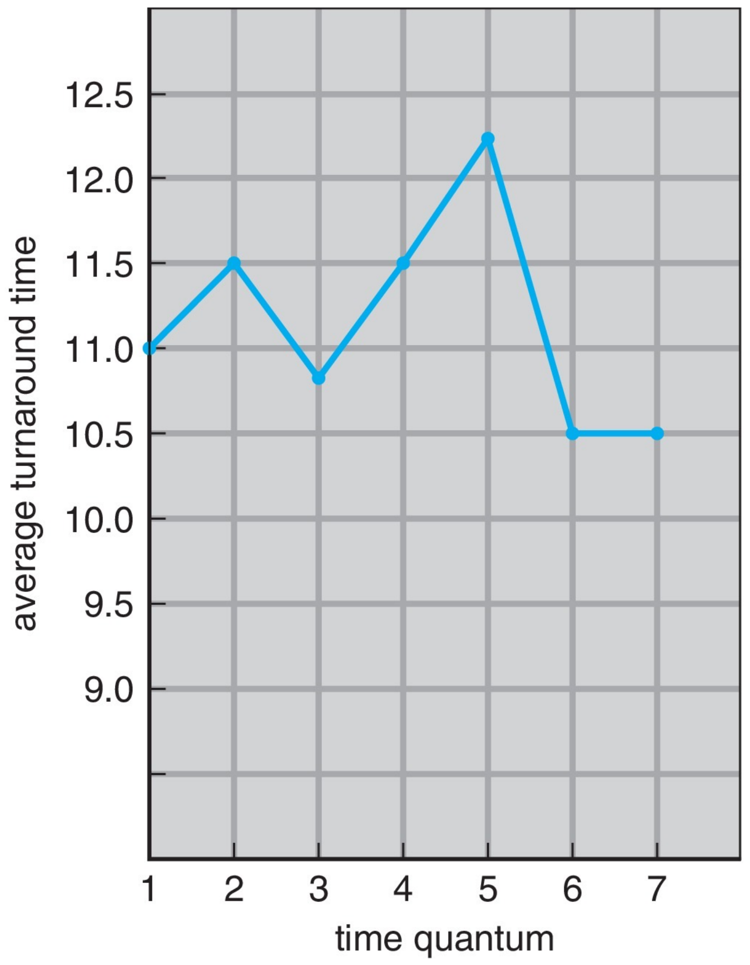


- Typically, higher average turnaround than SJF, but better ***response***
- *q* should be large compared to context switch time
  - **q** usually 10 milliseconds to 100 milliseconds,
  - Context switch < 10 microseconds

Time Quantum and Context Switch Time



Turnaround Time Varies With The Time Quantum



process	time
P_1	6
P_2	3
P_3	1
P_4	7

A rule of thump is that 80% of CPU bursts should be shorter than q

Priority Scheduling

Priority Scheduling

- A priority number (integer) is associated with each process
- The CPU is allocated to the process with the highest priority (**smallest integer ≡ highest priority**)
  - Preemptive
  - Nonpreemptive
- SJF is priority scheduling where priority is the ***next predicted CPU burst time***

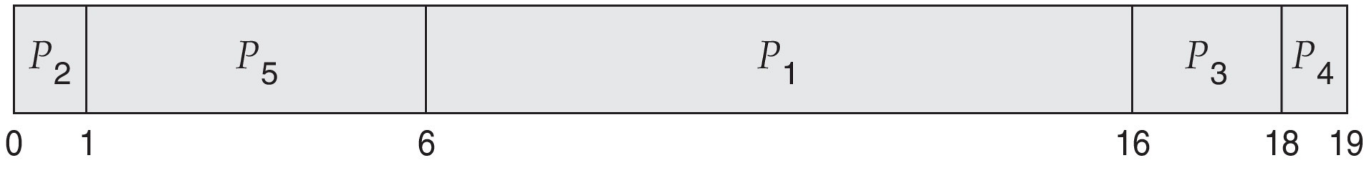
Priority Scheduling

- **Problem** ≡ **Starvation**
  - Low priority processes may never execute
- **Solution** ≡ **Aging**
  - As time progresses increase the priority of the process

Example of Priority Scheduling

Process	Burst Time	Priority
P_1	10	3
P_2	1	1
P_3	2	4
P_4	1	5
P_5	5	2

- Priority scheduling Gantt Chart

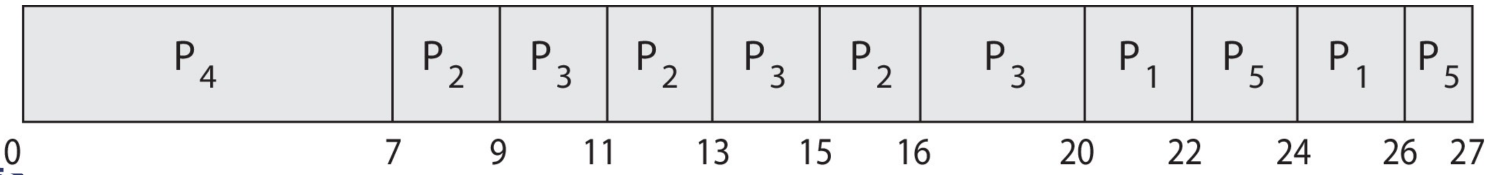


- Average waiting time = 8.2

Priority Scheduling w/ Round-Robin

Process	Burst Time	Priority
P_1	4	3
P_2	5	2
P_3	8	2
P_4	7	1
P_5	3	3

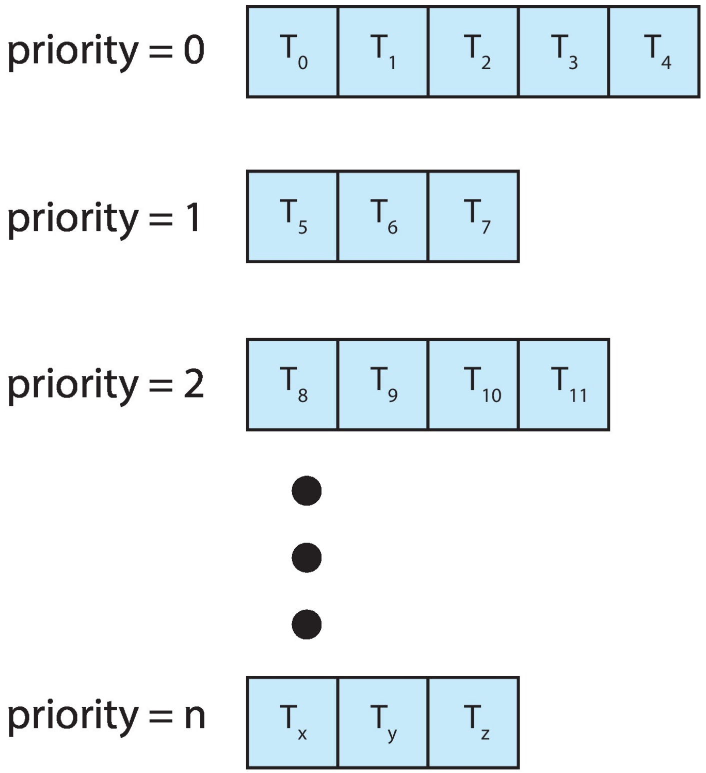
- Run the process with the highest priority. Processes with the same priority run round-robin
- Gantt Chart with time quantum = 2



Multilevel Queue Scheduling

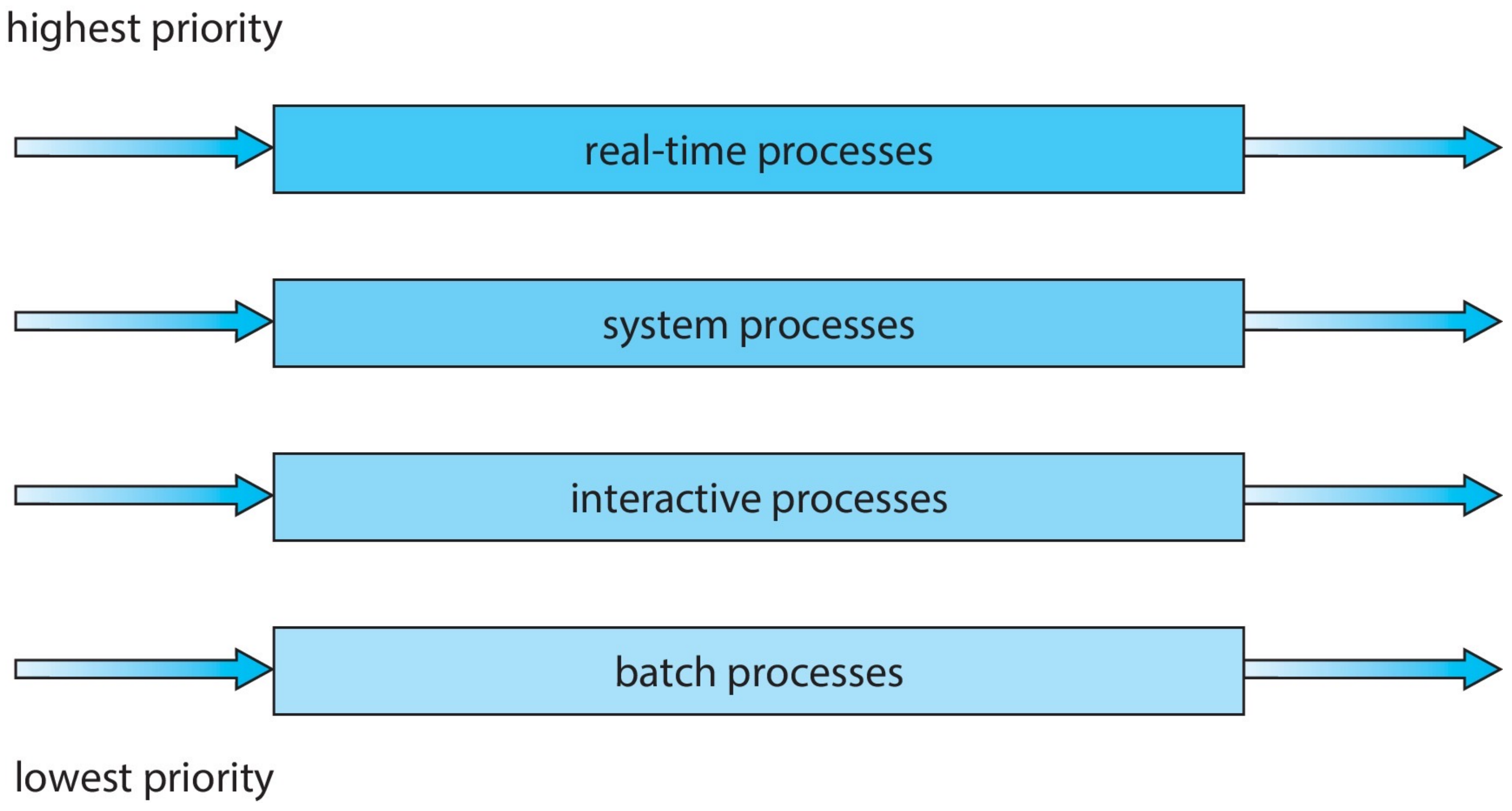
Multilevel Queue

- With priority scheduling, have separate queues for each priority.
- Schedule the process in the highest-priority queue!



Multilevel Queue

- Prioritization based upon process type



Multilevel Feedback Queue

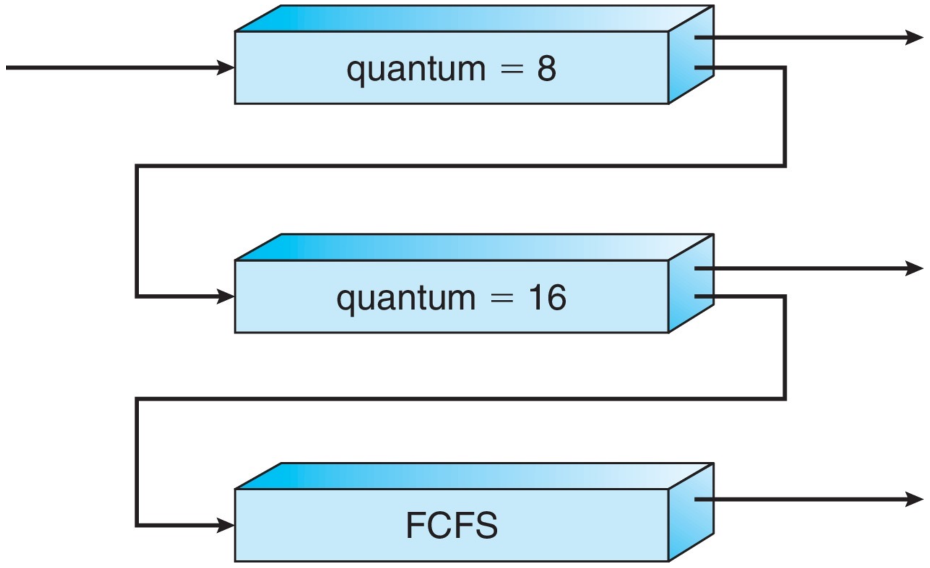
- A process can move between the various queues.

- Multilevel-feedback-queue defined by the following parameters:
  - Number of queues
  - Scheduling algorithms for each queue
  - Method used to determine when to upgrade a process
  - Method used to determine when to demote a process
  - Method used to determine which queue a process will enter when that process needs service

- **Aging** can be implemented using multilevel feedback queue

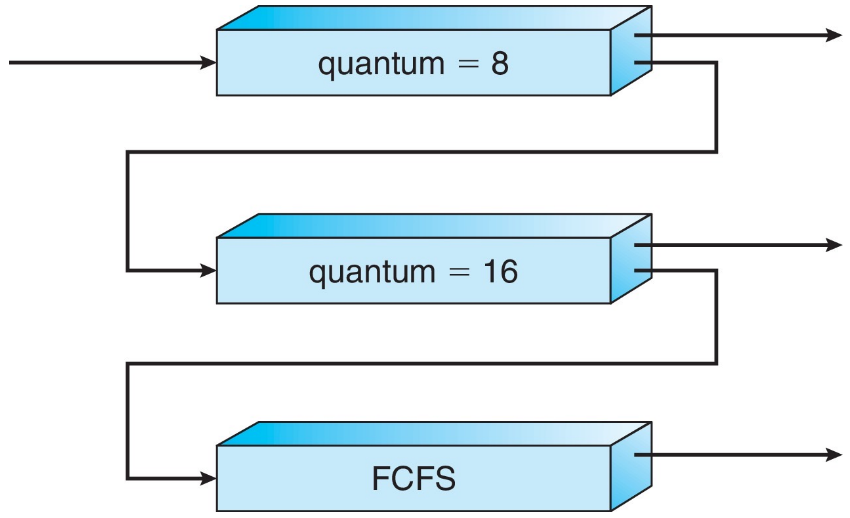
Example of Multilevel Feedback Queue

- Three queues:
  - Q_0 – RR with time quantum 8 milliseconds
  - Q_1 – RR time quantum 16 milliseconds
  - Q_2 – FCFS



Example of Multilevel Feedback Queue (cont.)

- Scheduling
  - A new process enters queue Q_0 which is served in RR
    - When it gains CPU, the process receives 8 milliseconds
    - If it does not finish in 8 milliseconds, the process is moved to queue Q_1
  - At Q_1 job is again served in RR and receives 16 additional milliseconds
    - If it still does not complete, it is preempted and moved to queue Q_2


quantum = 8
quantum = 16
FCFS