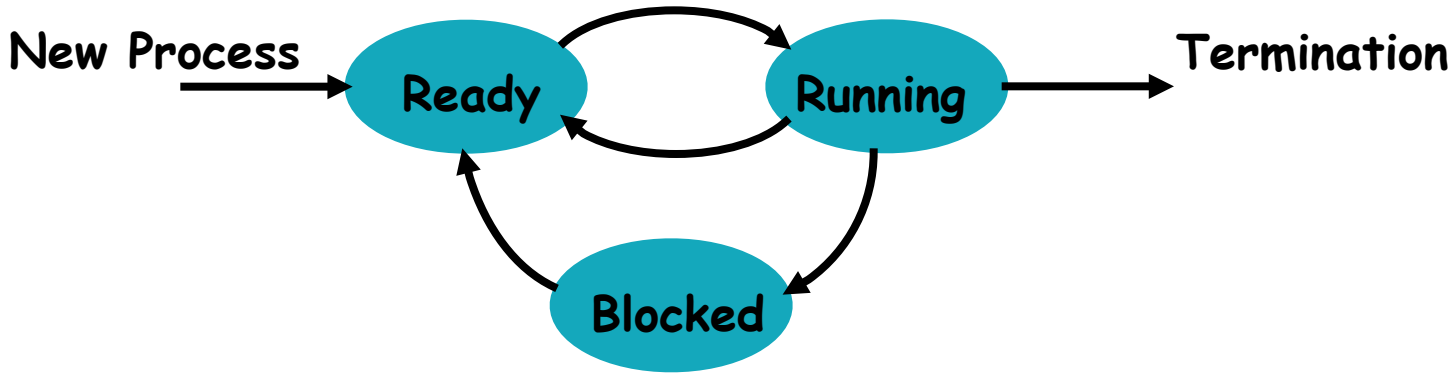
بسم الله الرحمن الرحیم

۱ «سیستم عامل»

جلسه ۱۲: زمان‌بندی

Process state model



CPU scheduling criteria

- **CPU Utilization** – how busy is the CPU?
- **Throughput** – how many jobs finished/unit time?
- **Turnaround Time** – how long from job submission to job termination?
- **Response Time** – how long (on average) does it take to get a "response" from a "stimulus"?
- **Missed deadlines** – were any deadlines missed?

Scheduler options

- **Priorities**
  - May use priorities to determine who runs next
  - Dynamic vs. Static algorithms
    - **Dynamically alter the priority of the tasks while they are in the system (possibly with feedback)**
    - **Static algorithms typically assign a fixed priority when the job is initially started.**

- **Preemptive vs. Nonpreemptive**
  - Preemptive systems allow the task to be interrupted at any time so that the O.S. can take over again.

Scheduling policies

- First-Come, First Served (FIFO)
- Shortest Job First (non-preemptive)
- Shortest Job First (with preemption)
- Round-Robin Scheduling
- Priority Scheduling
- Real-Time Scheduling

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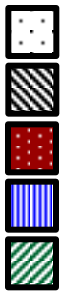

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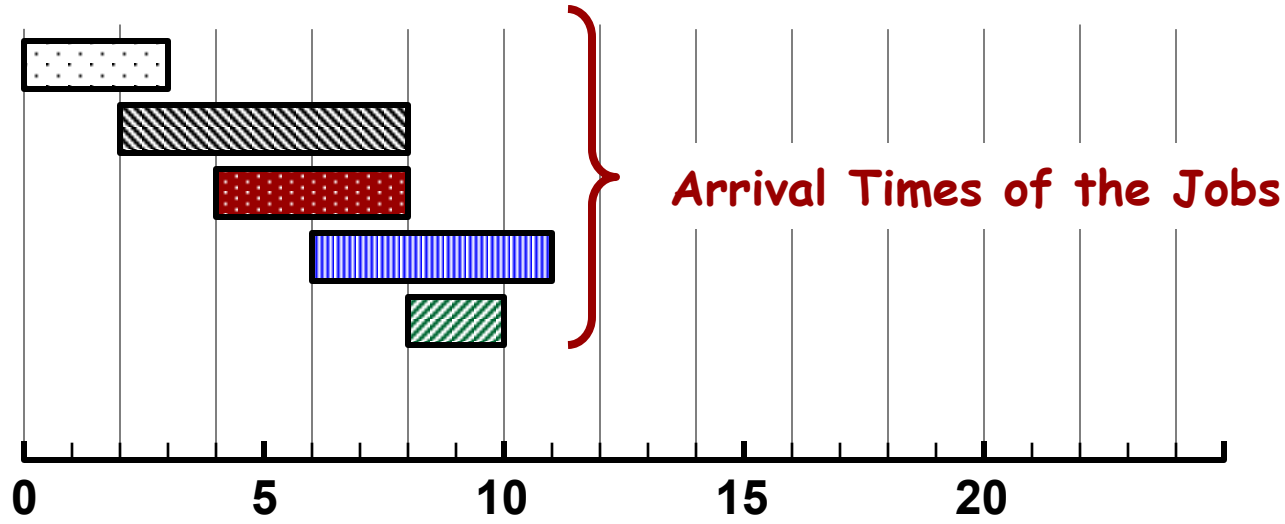

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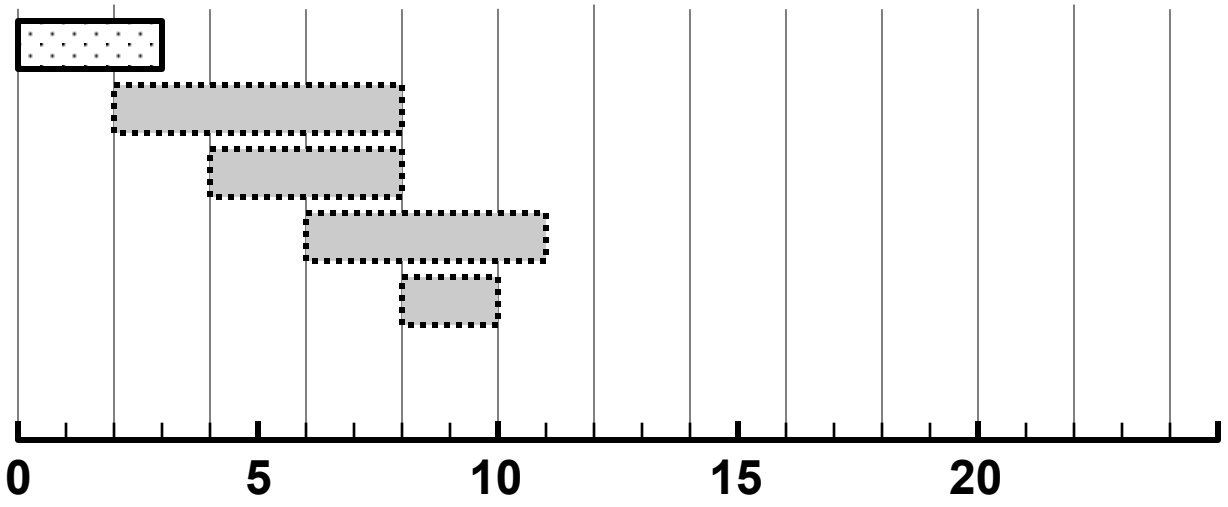

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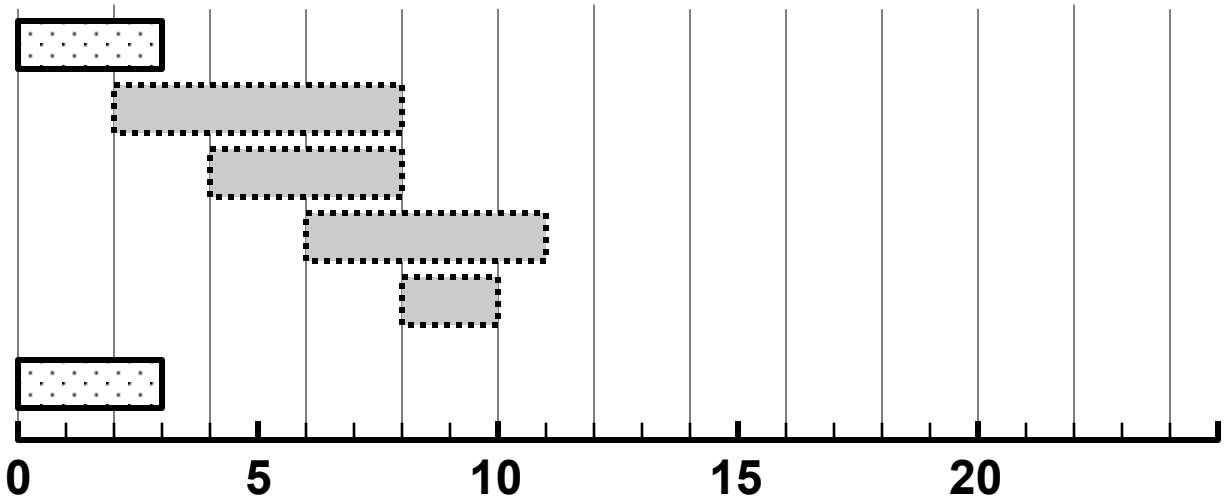

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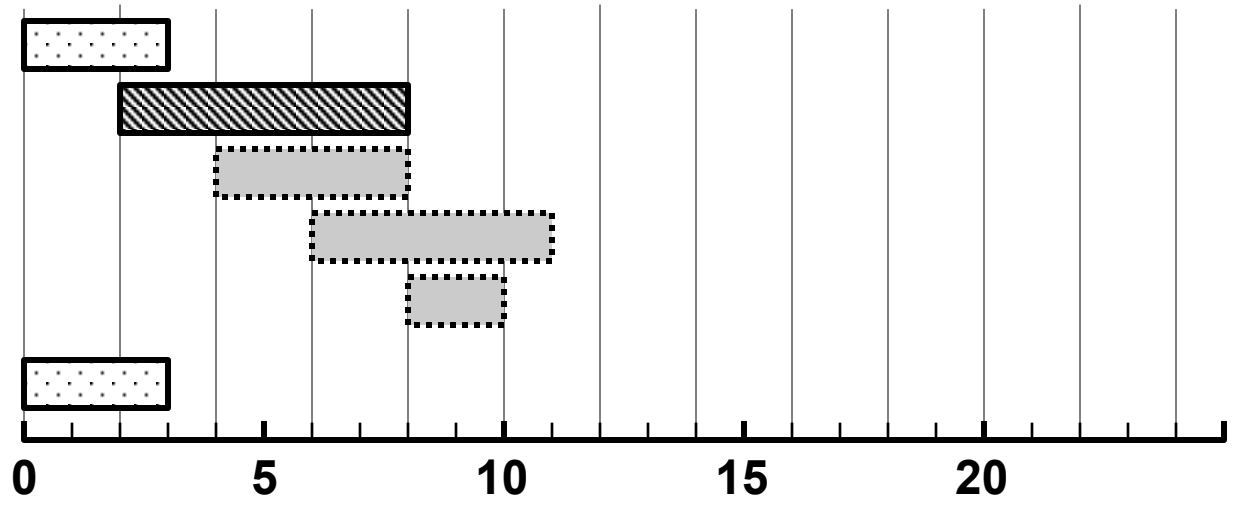

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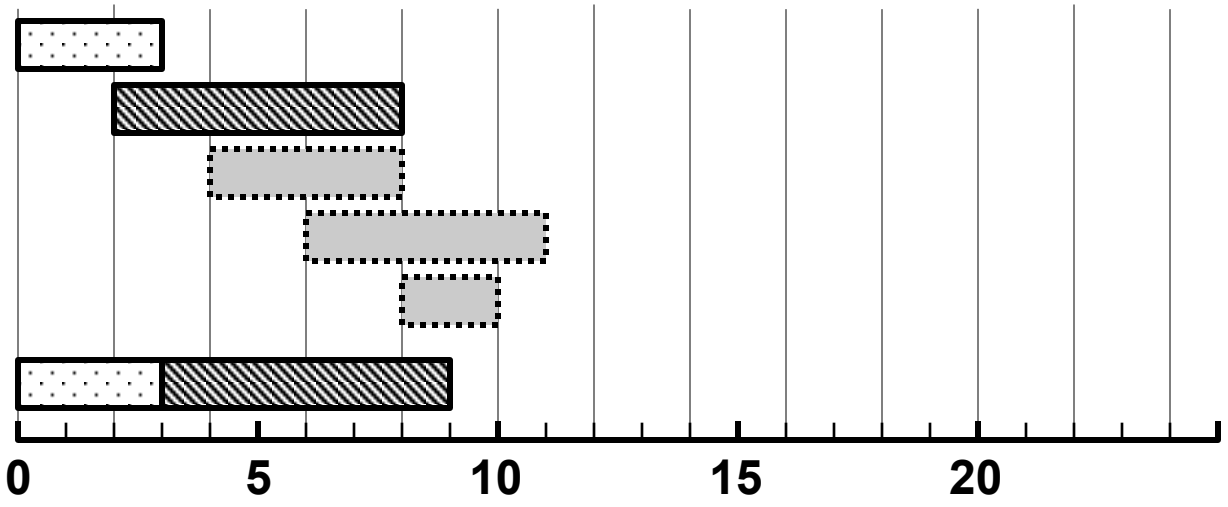

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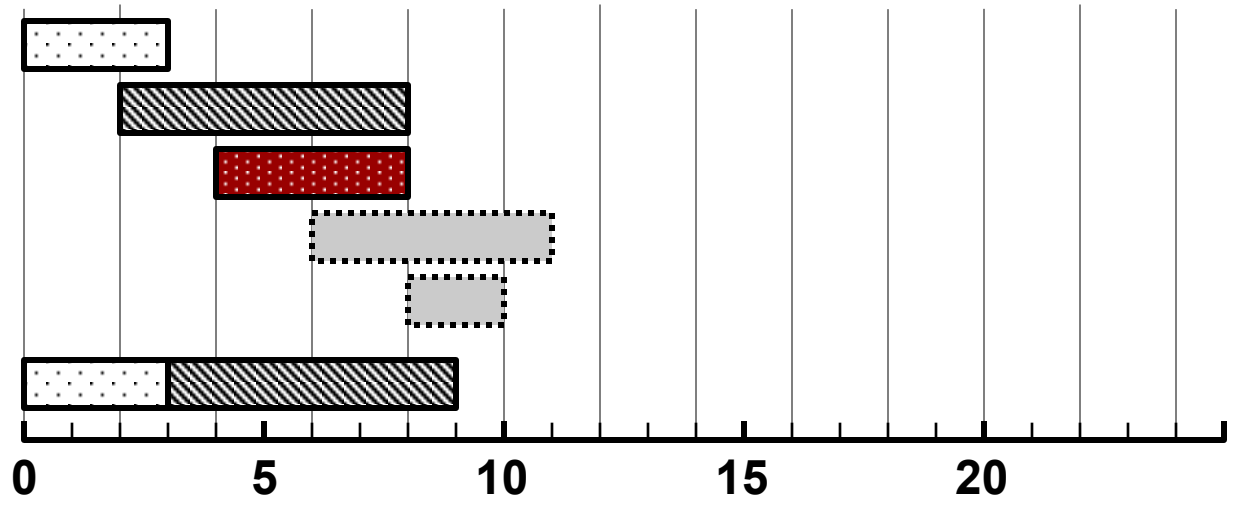

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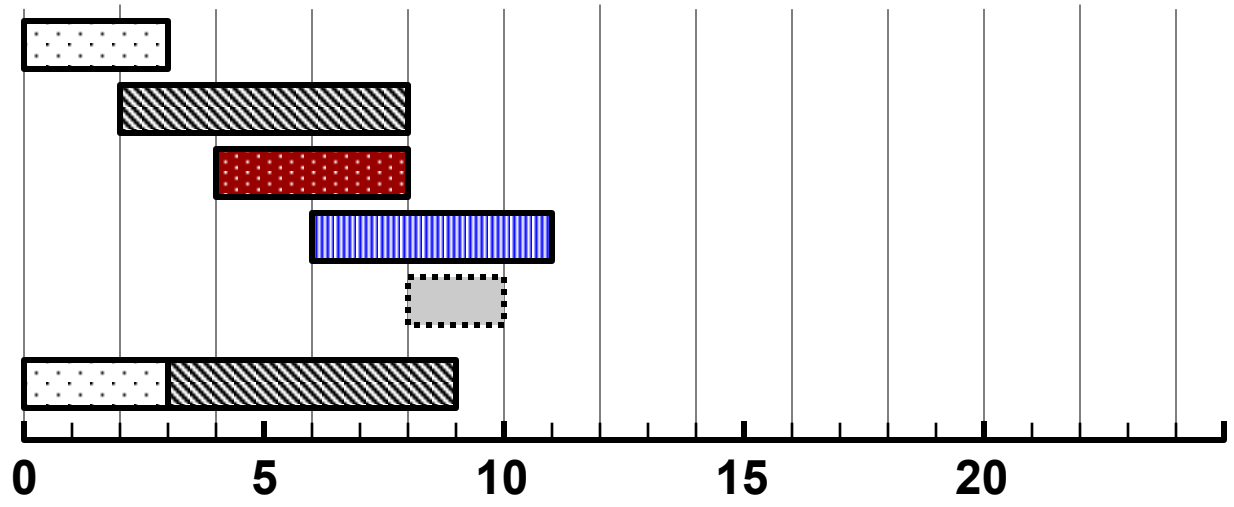

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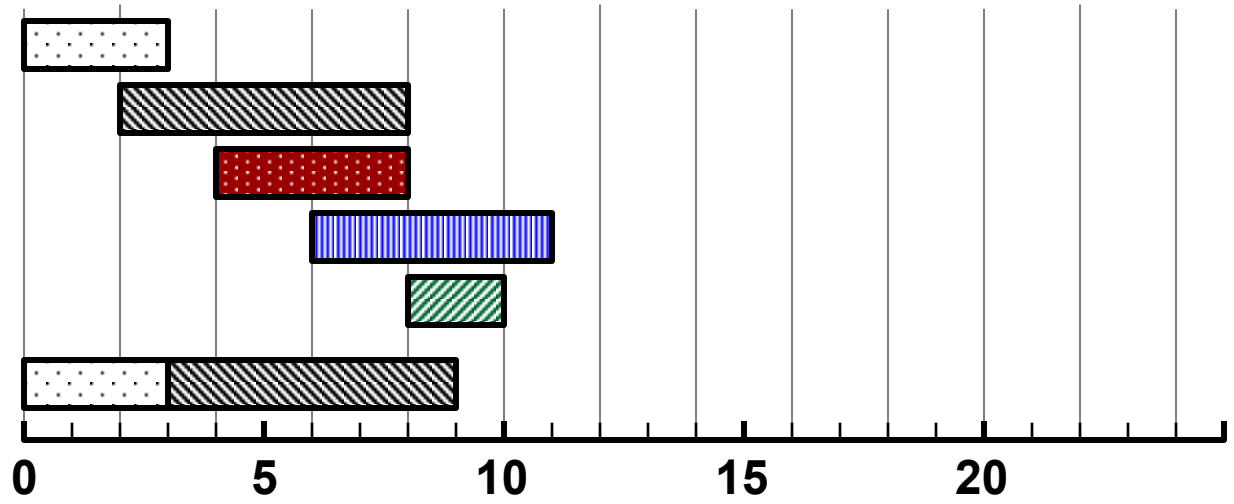

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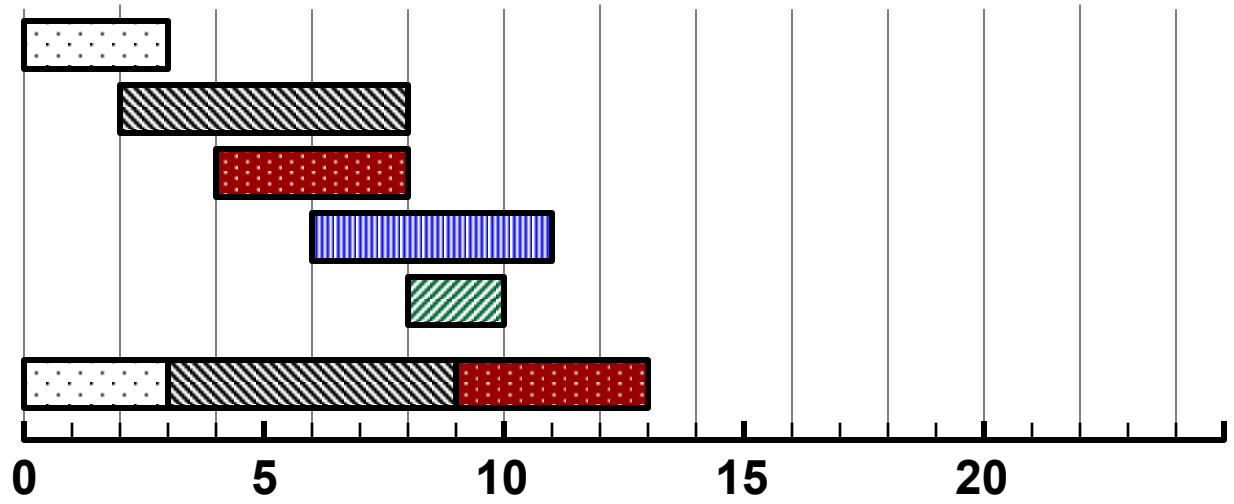

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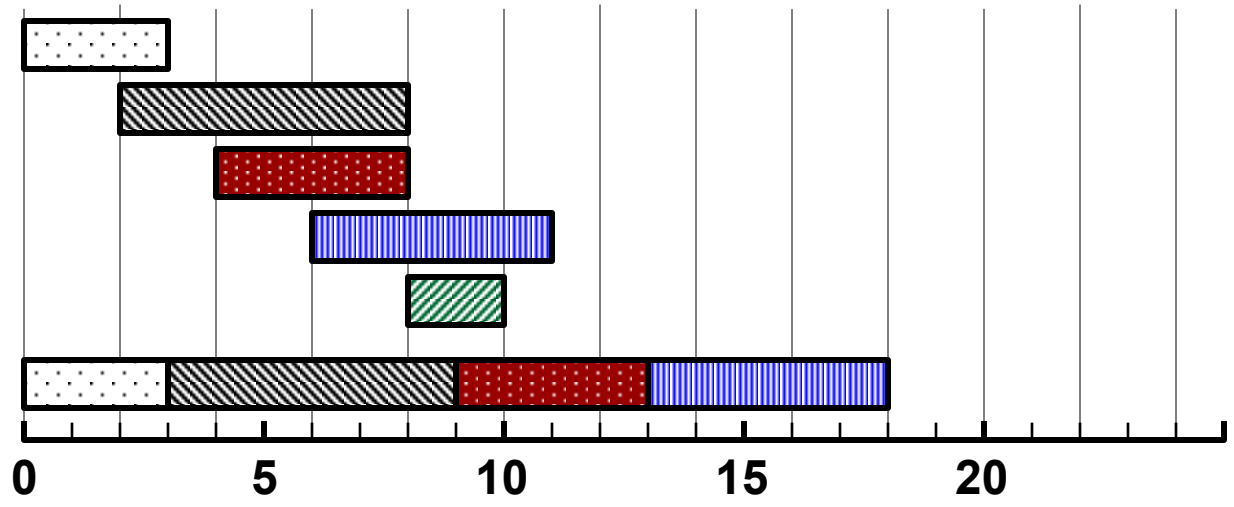

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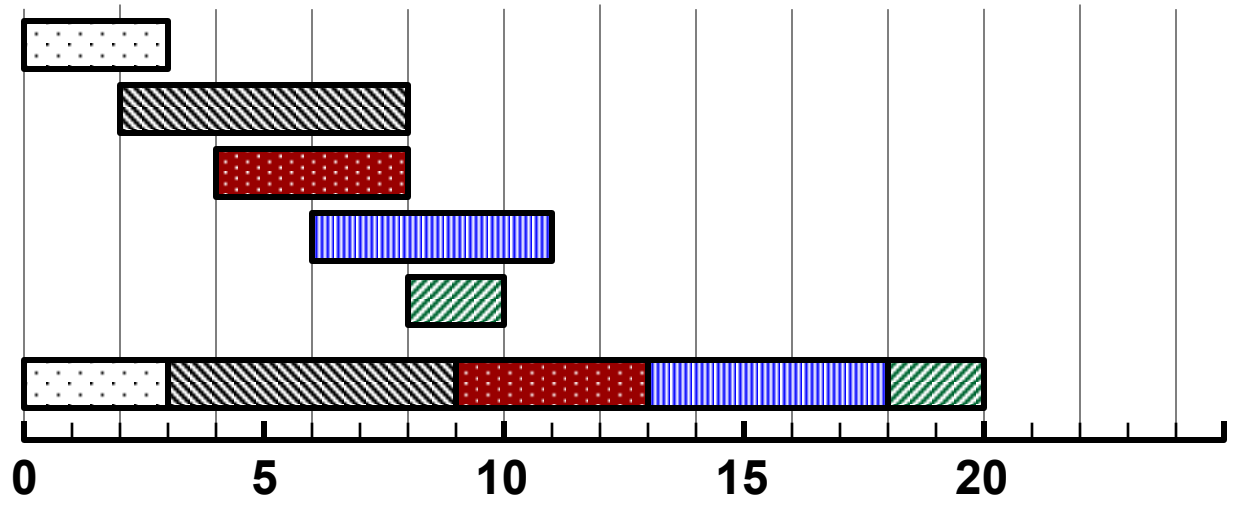

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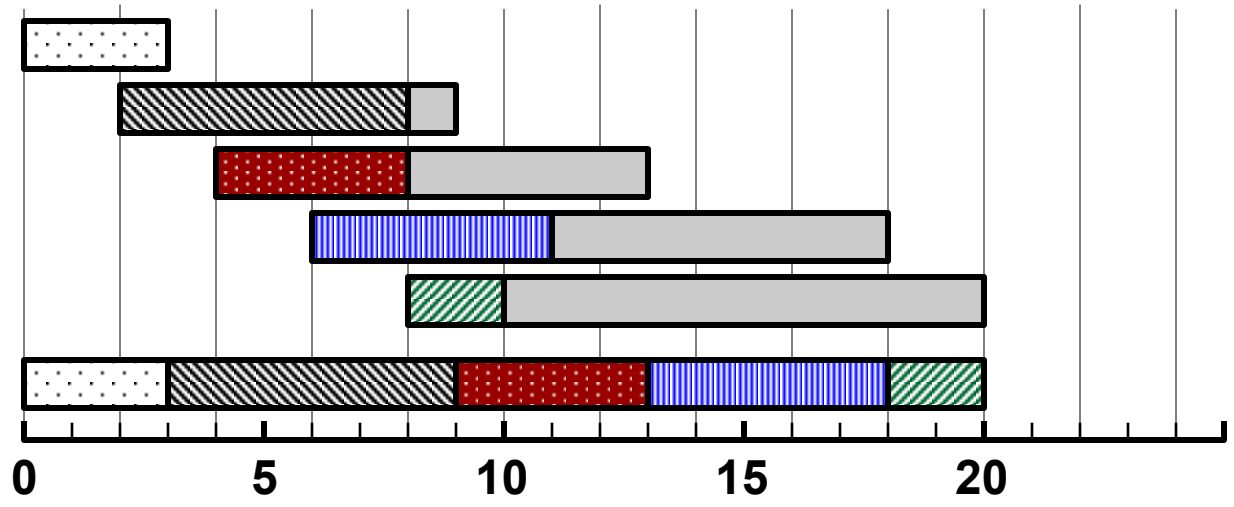

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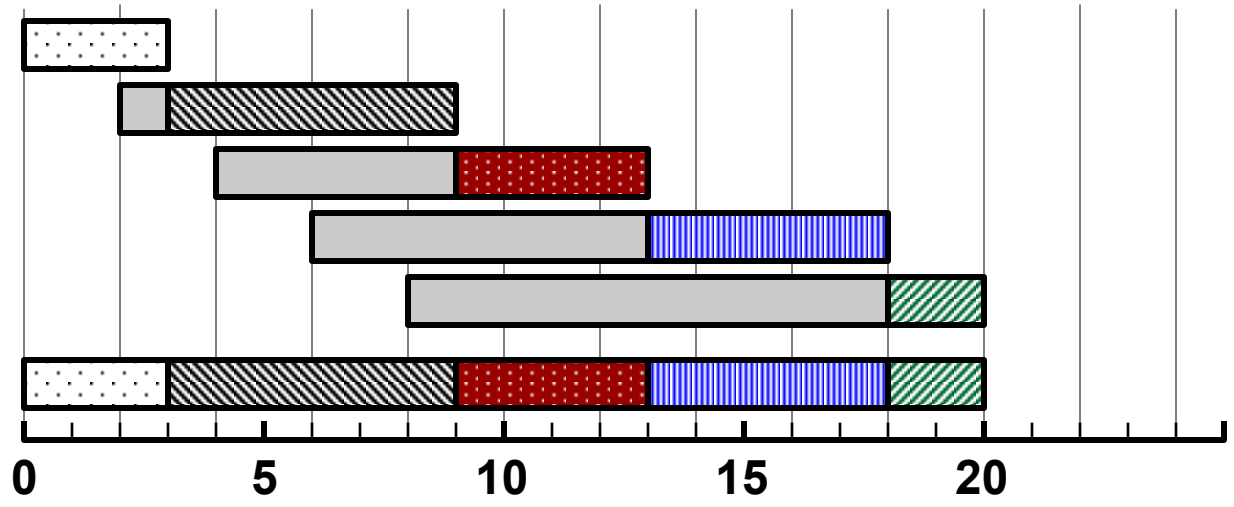

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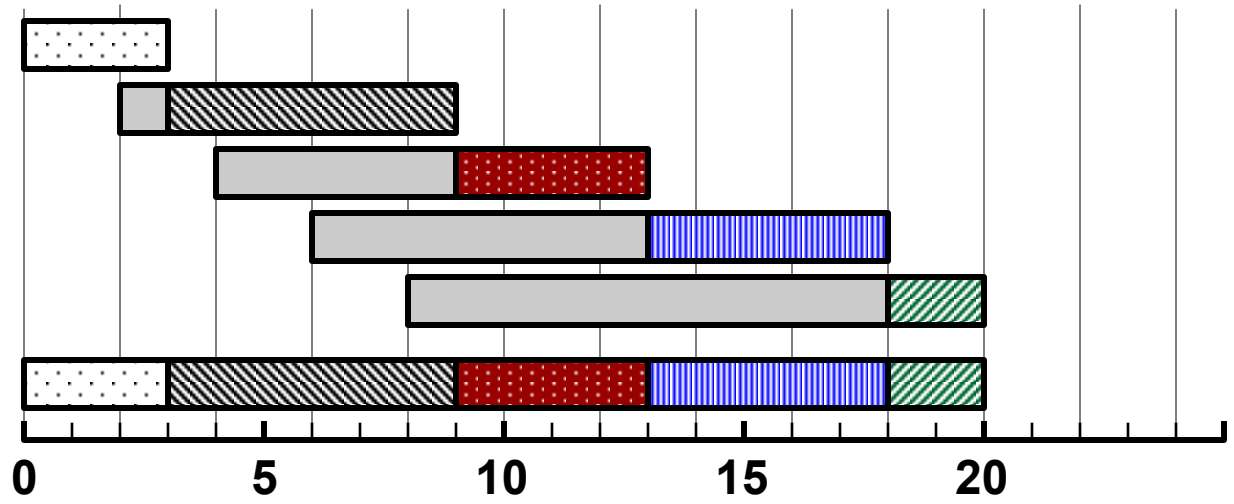

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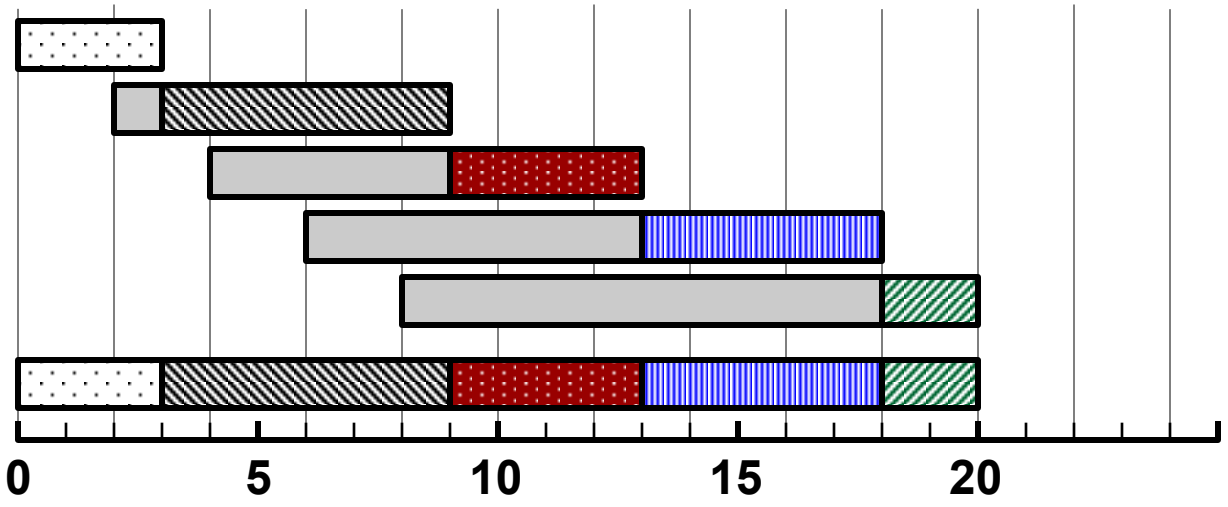

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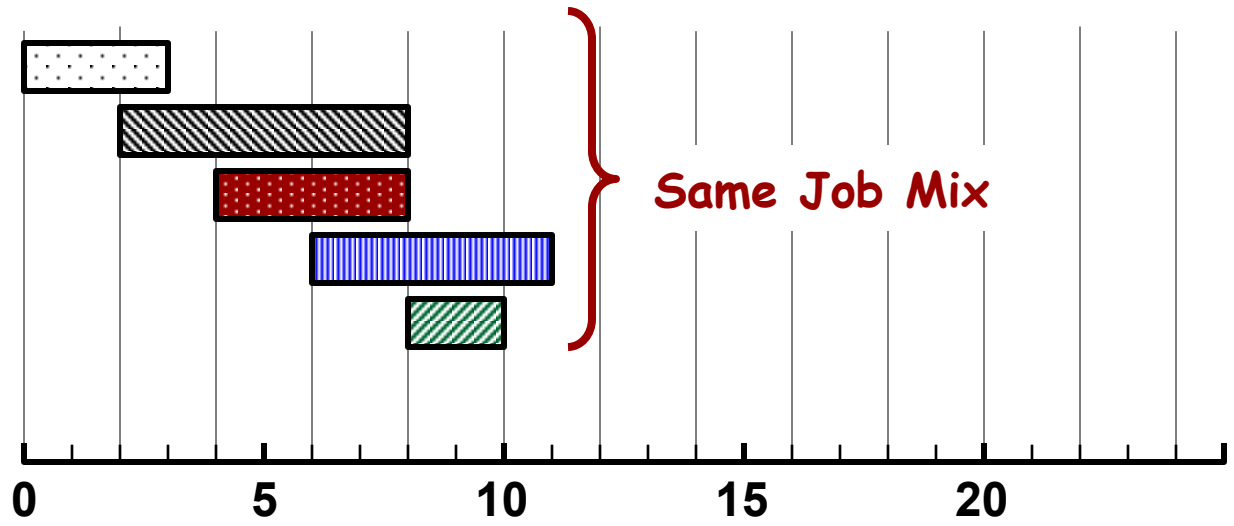

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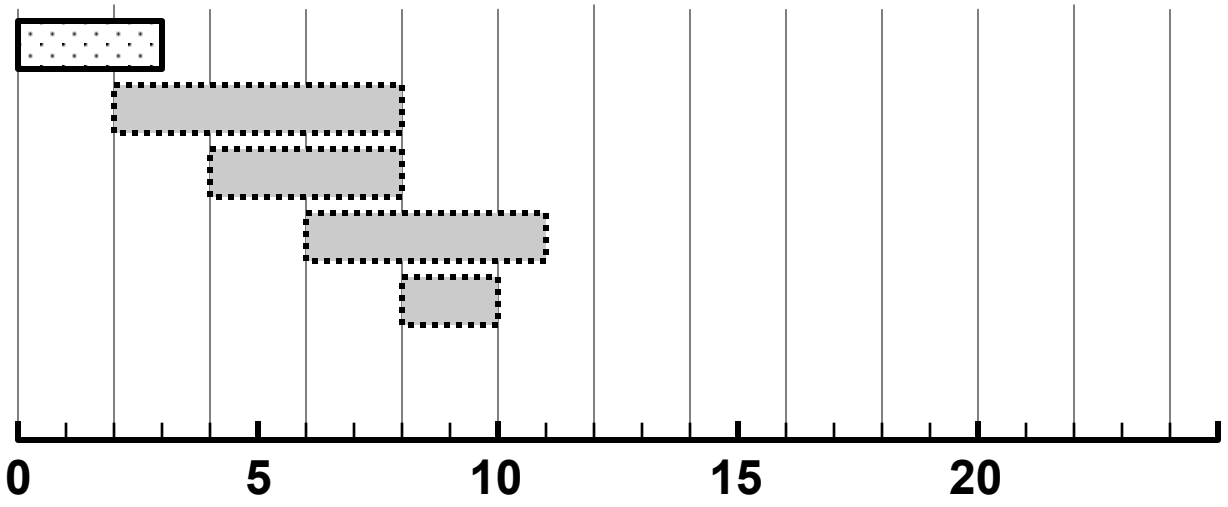

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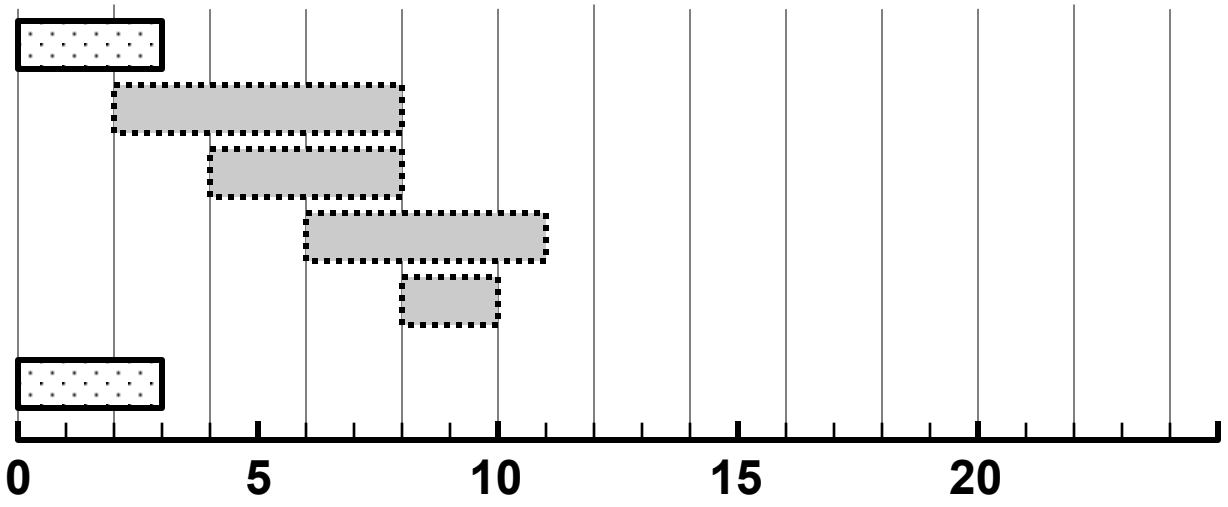

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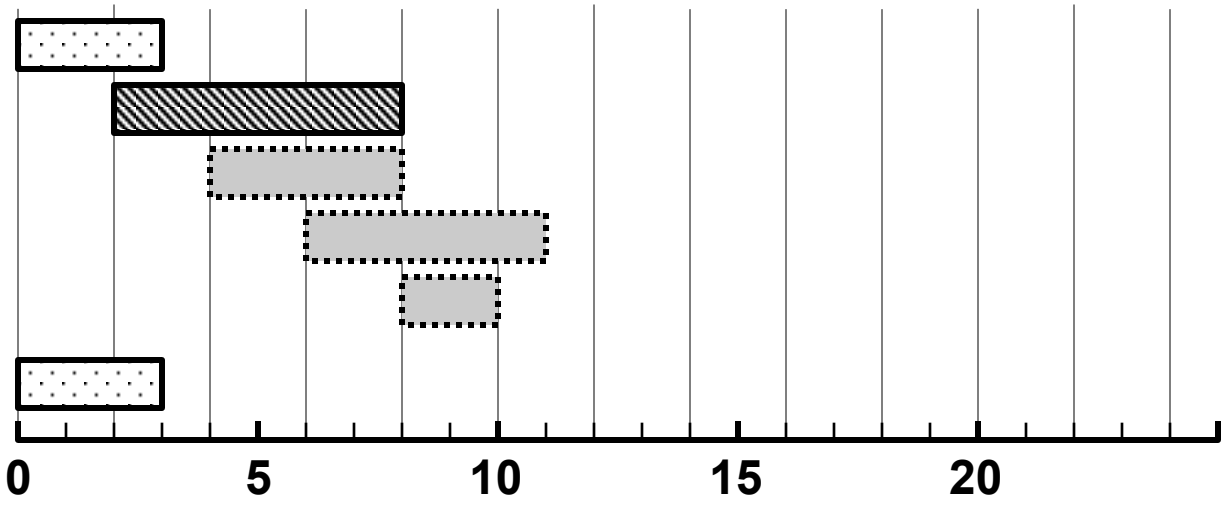

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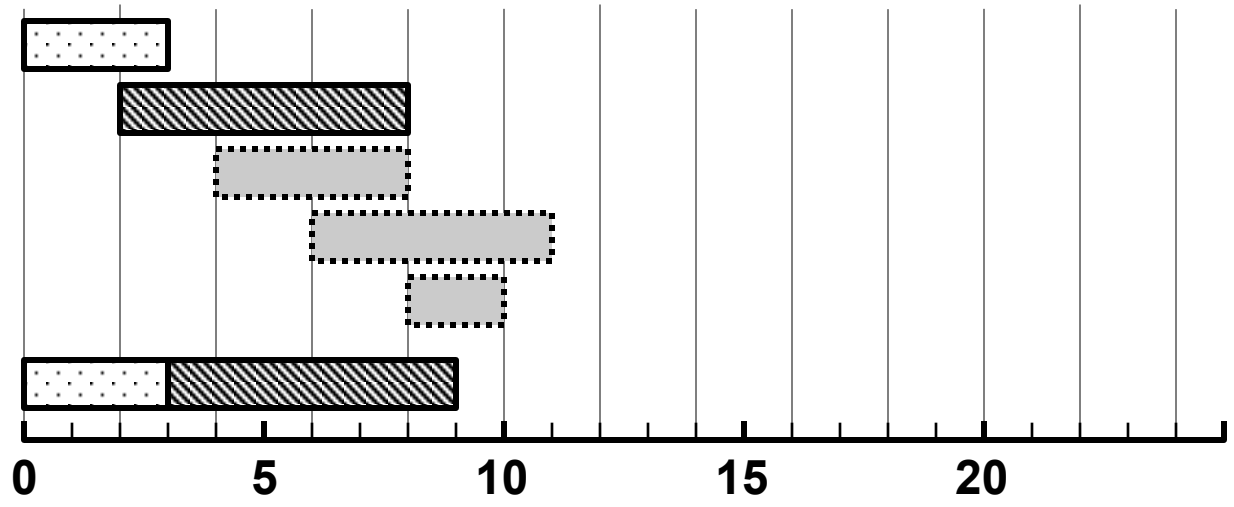

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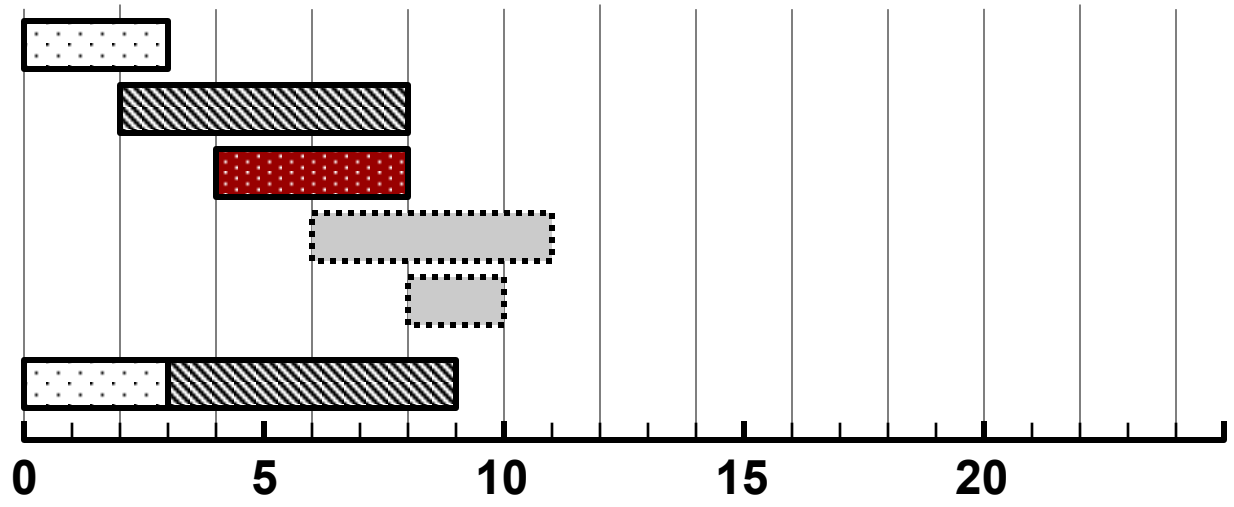

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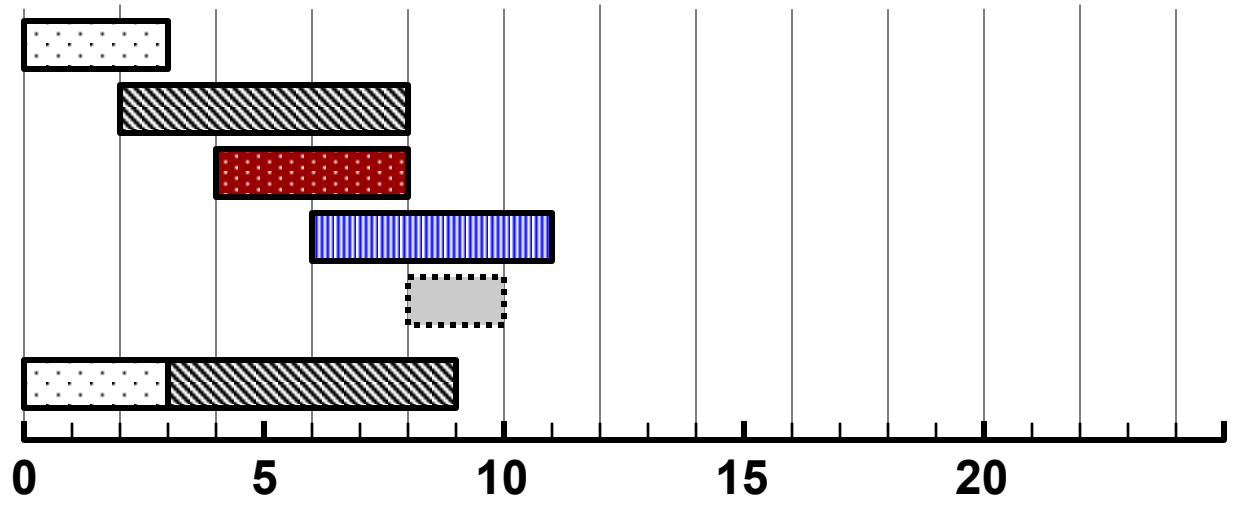

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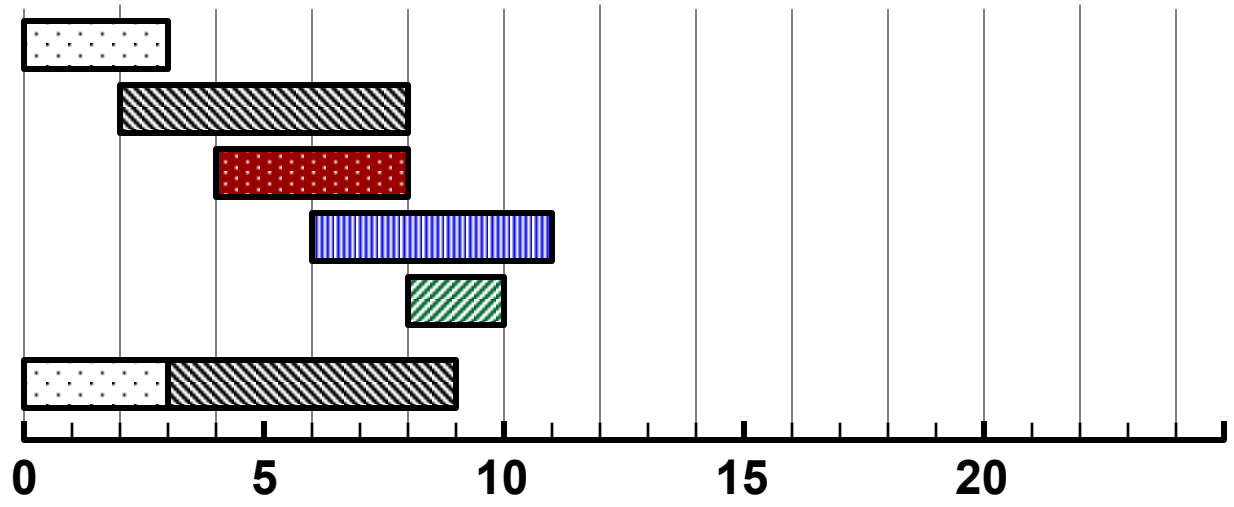

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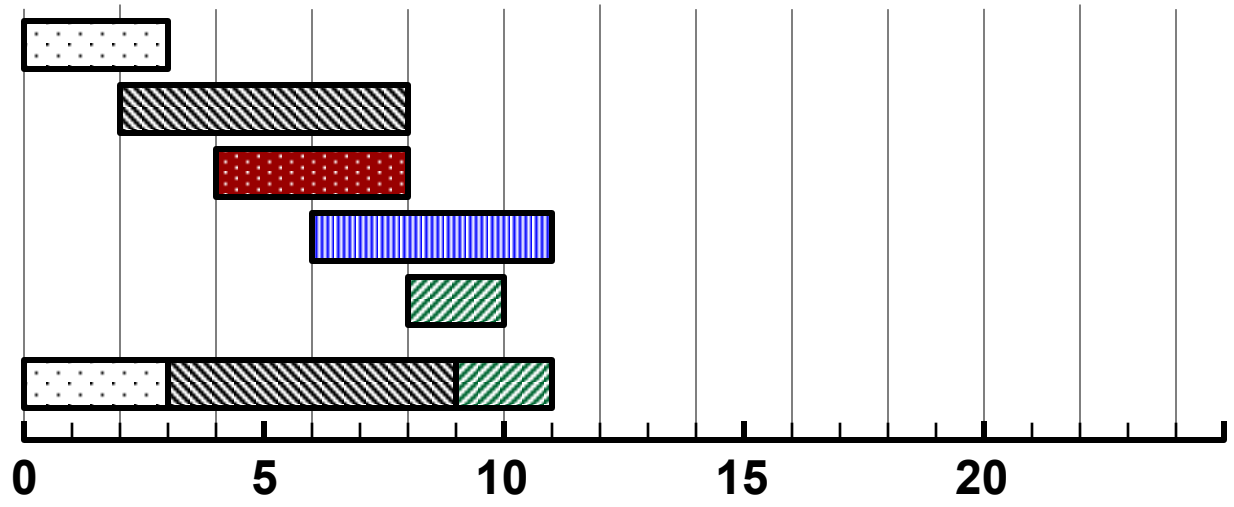

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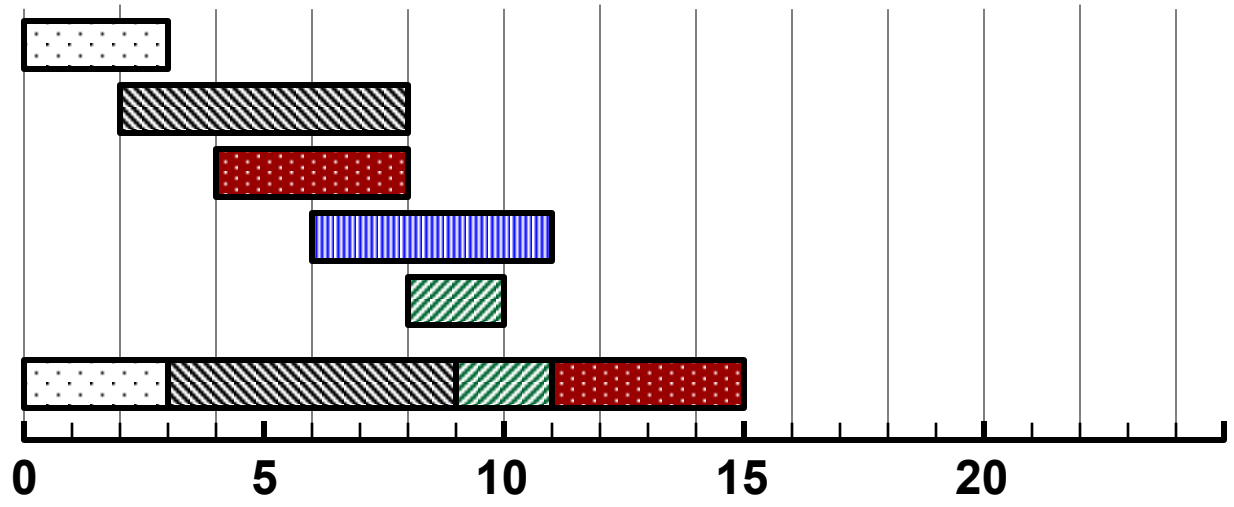

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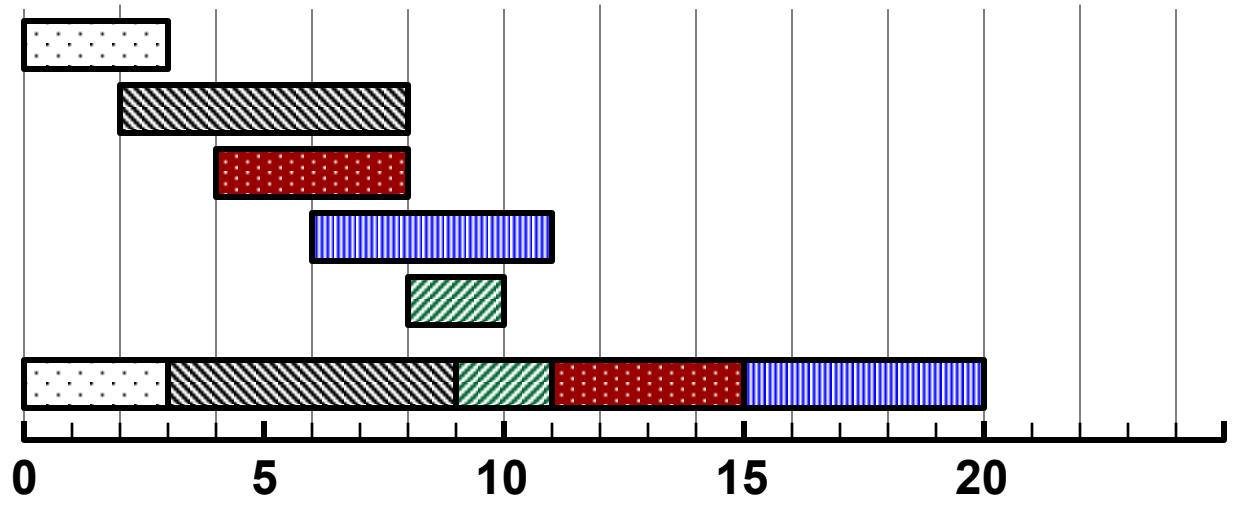

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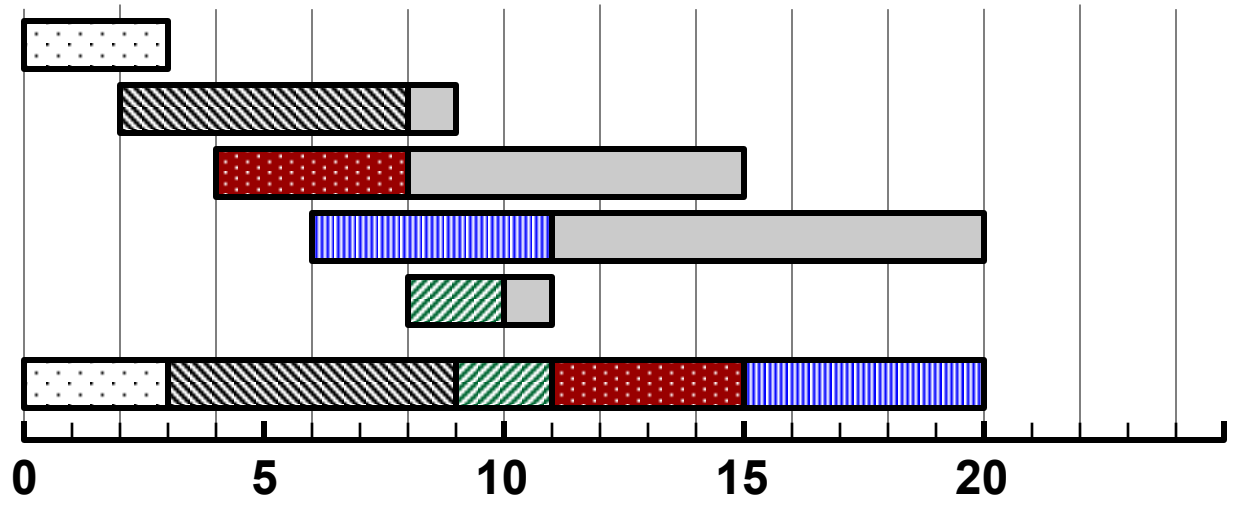

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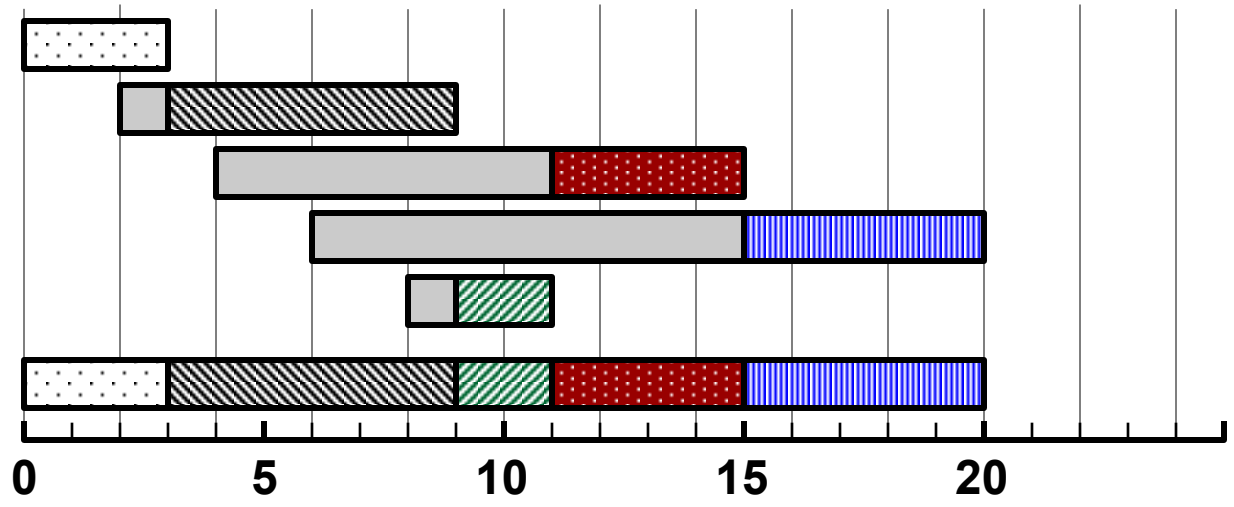

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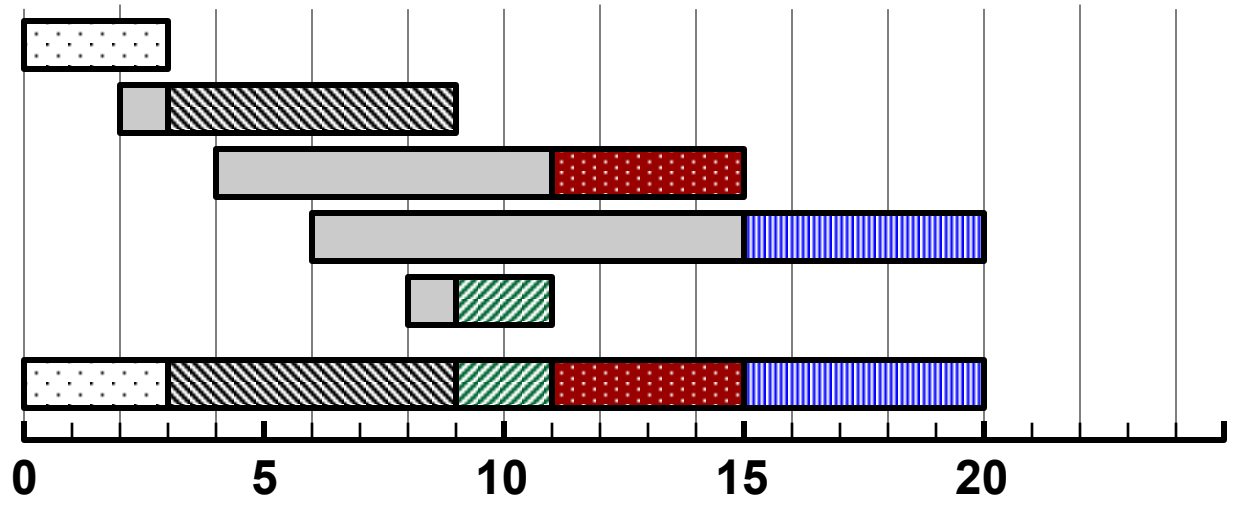

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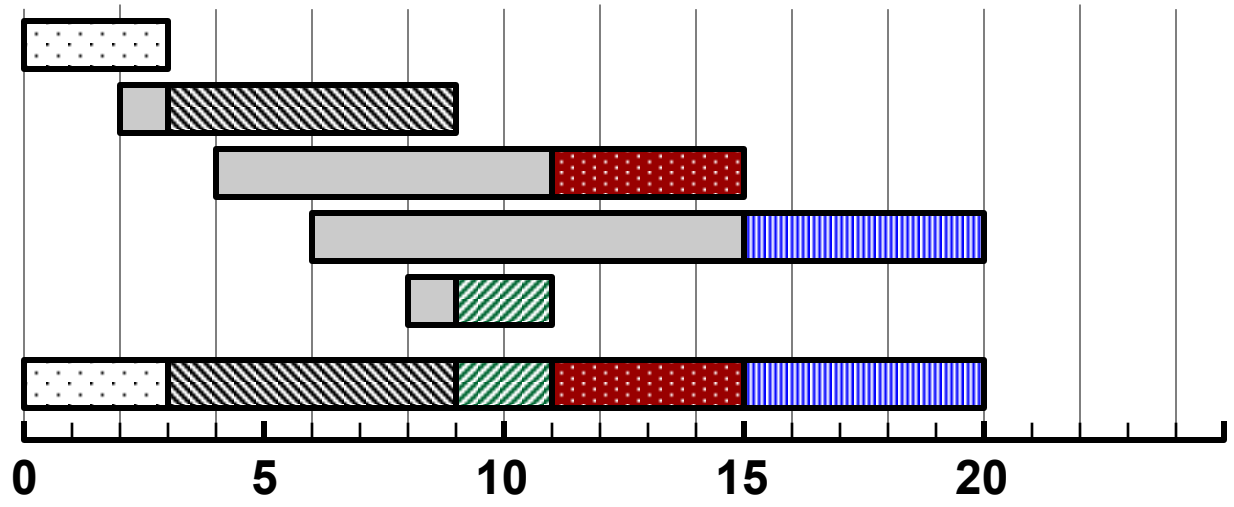
4	6	5	9	14
5	8	2	1	3



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- Preemptive version of SJF

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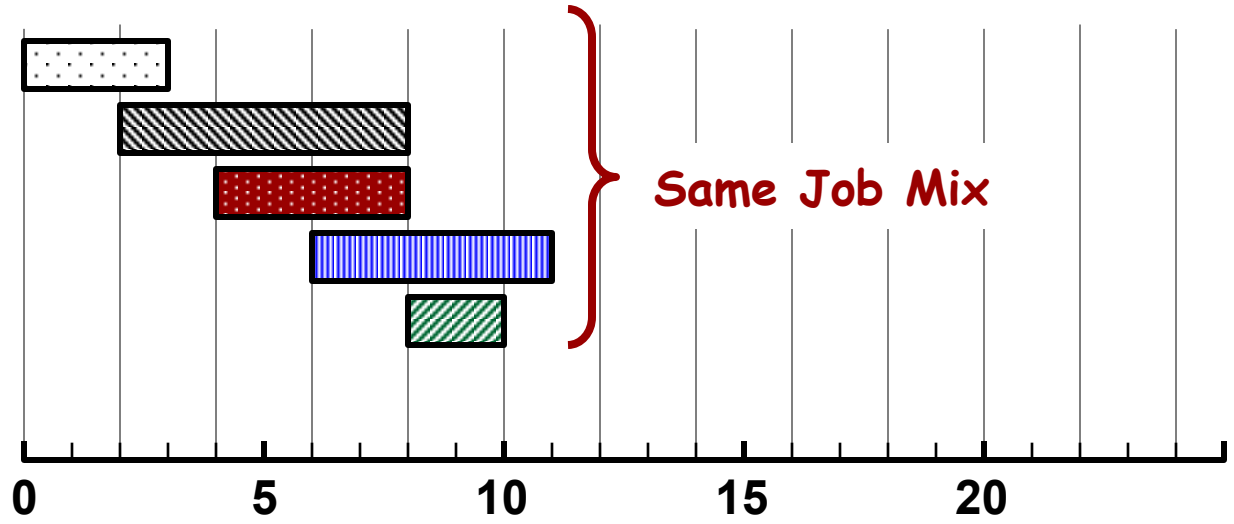

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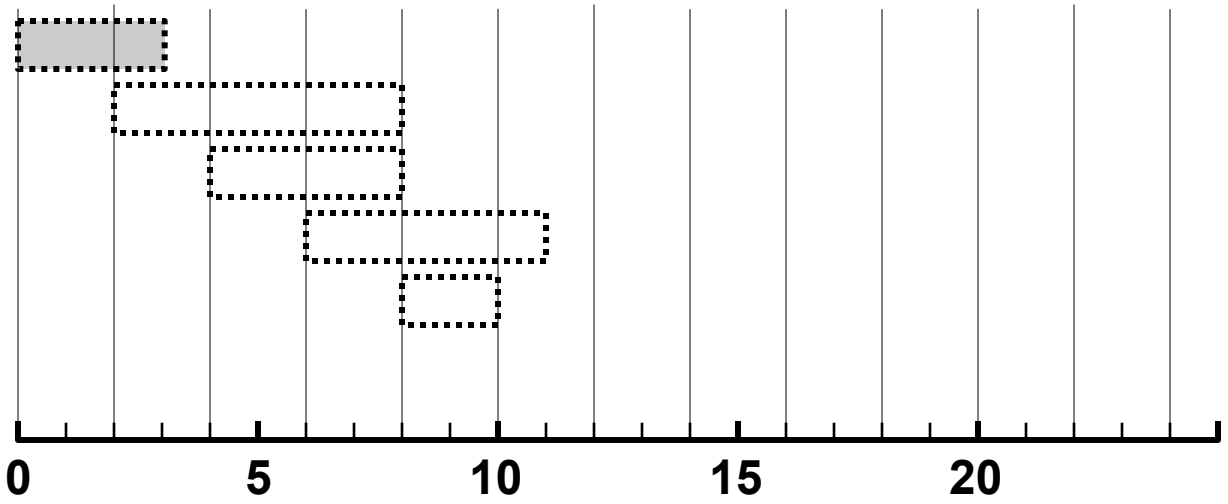

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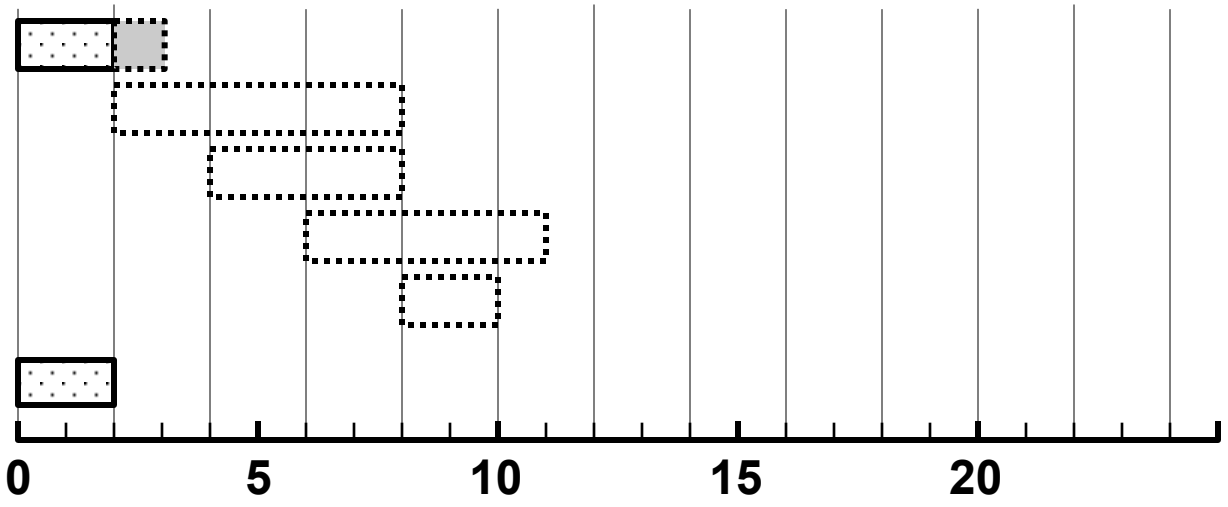
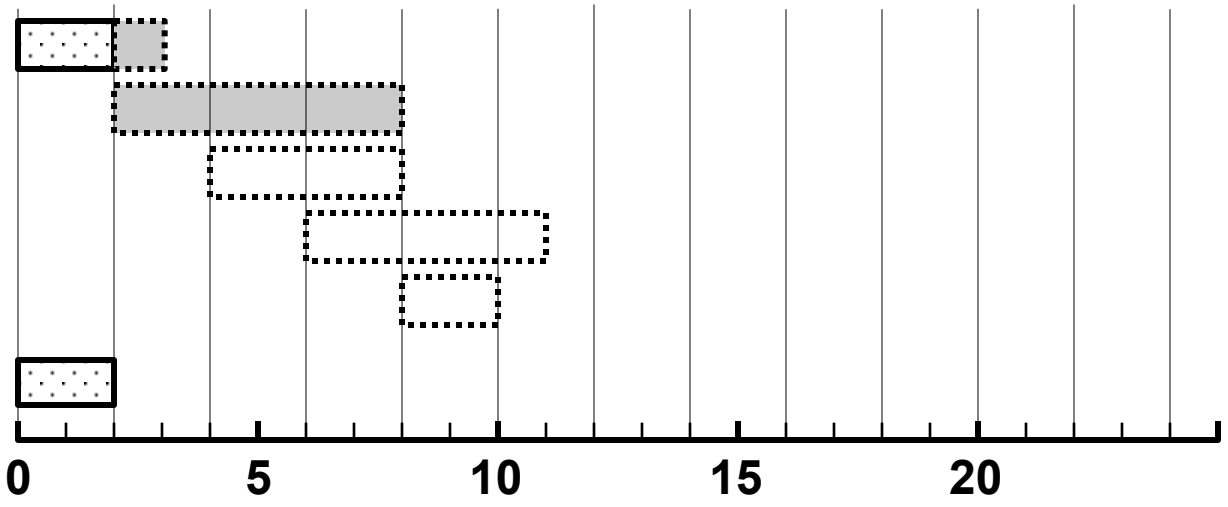


Shortest Remaining Time

- Preemptive version of SJF

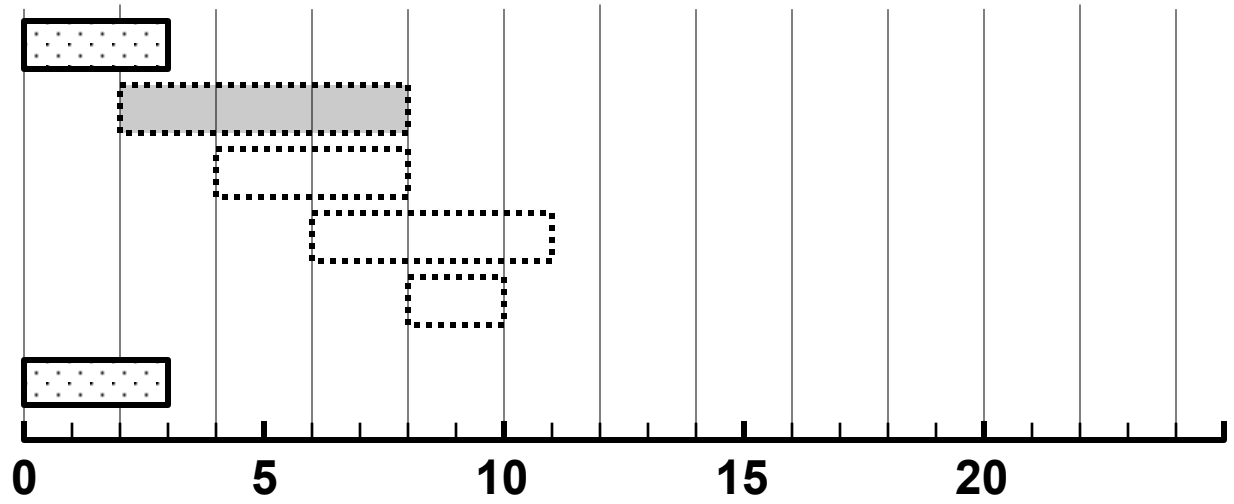
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

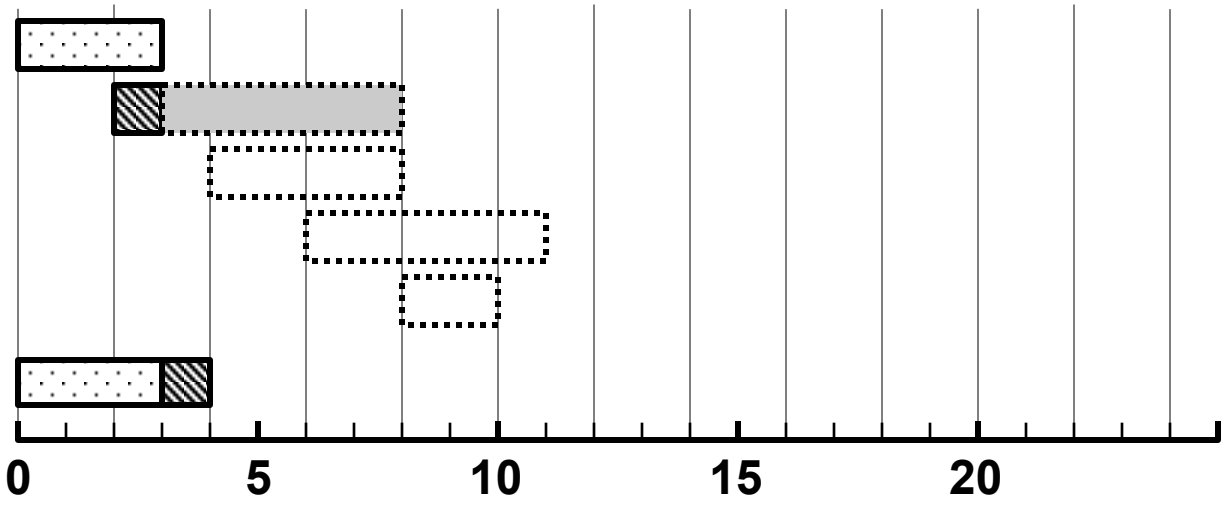
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

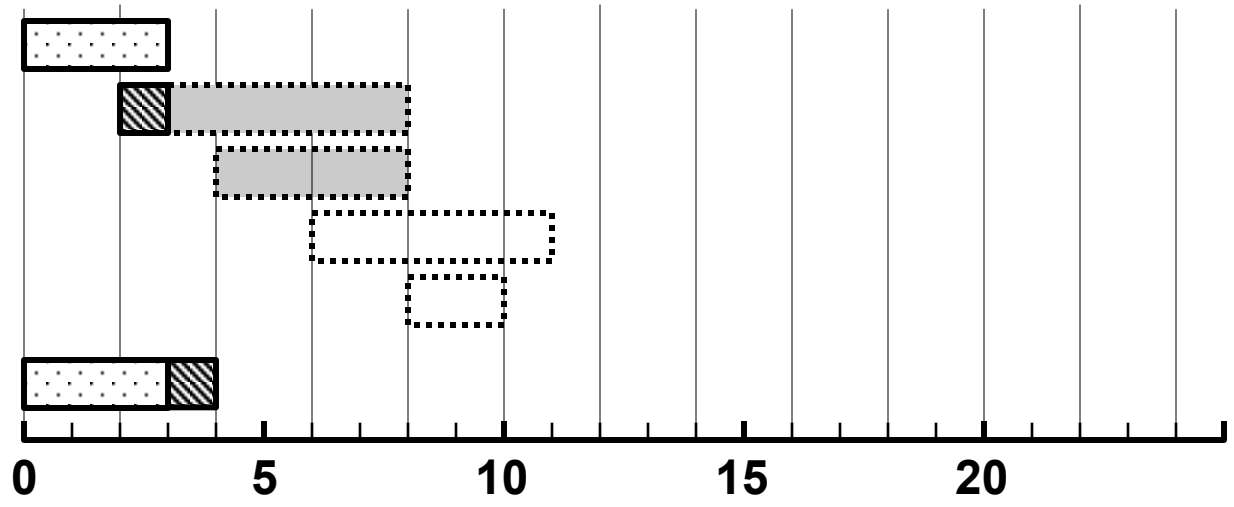
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

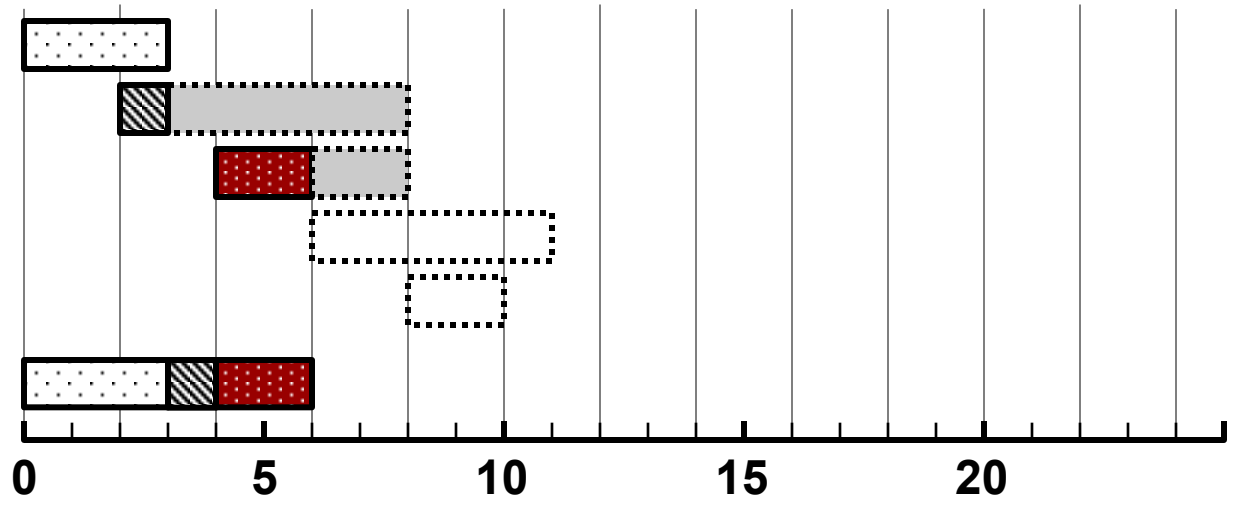
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

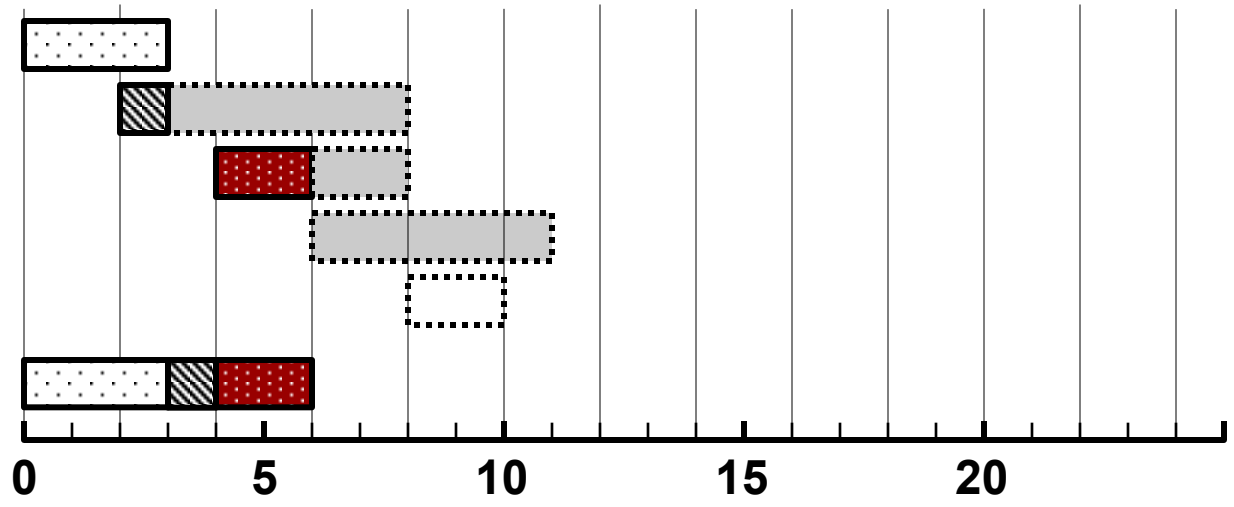
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

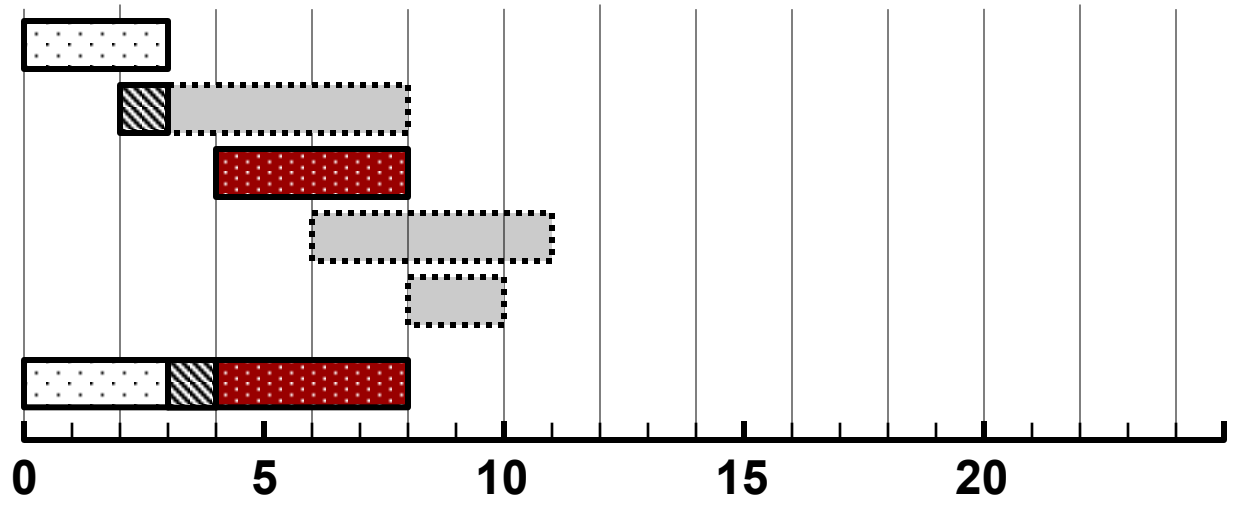
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

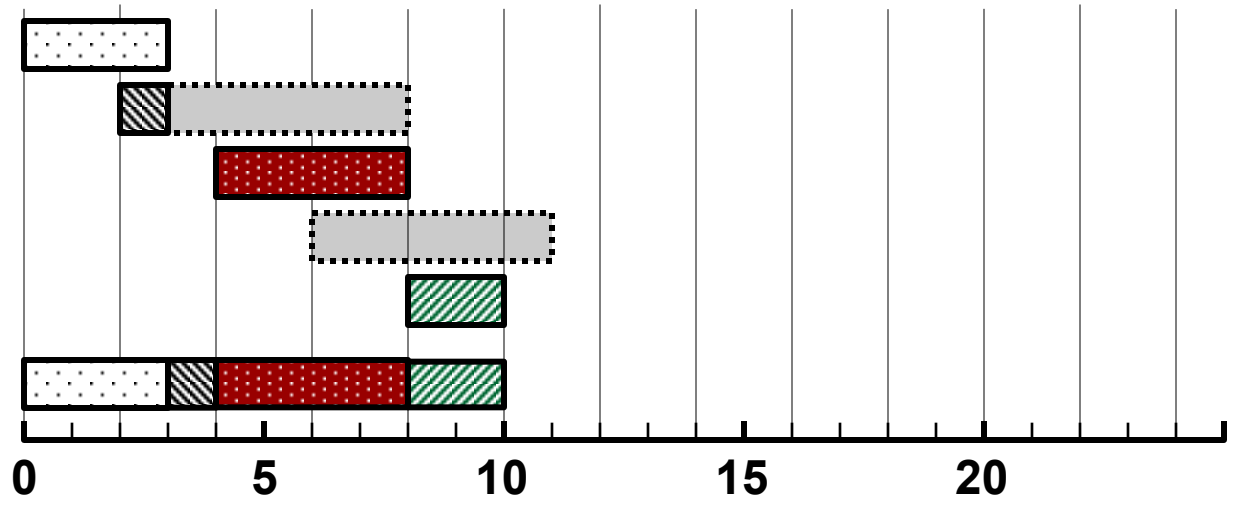
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

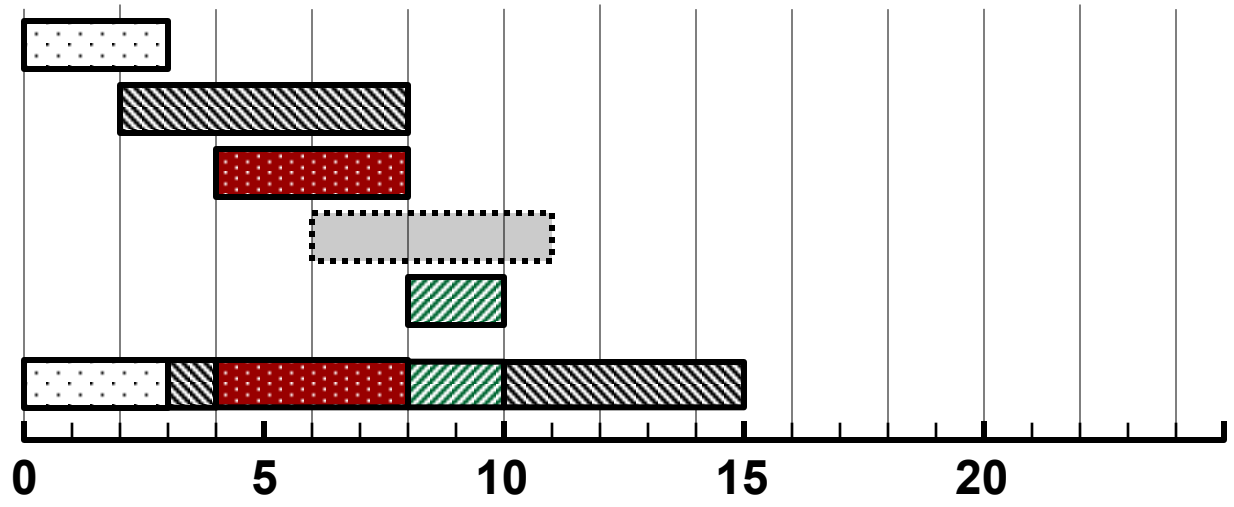
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

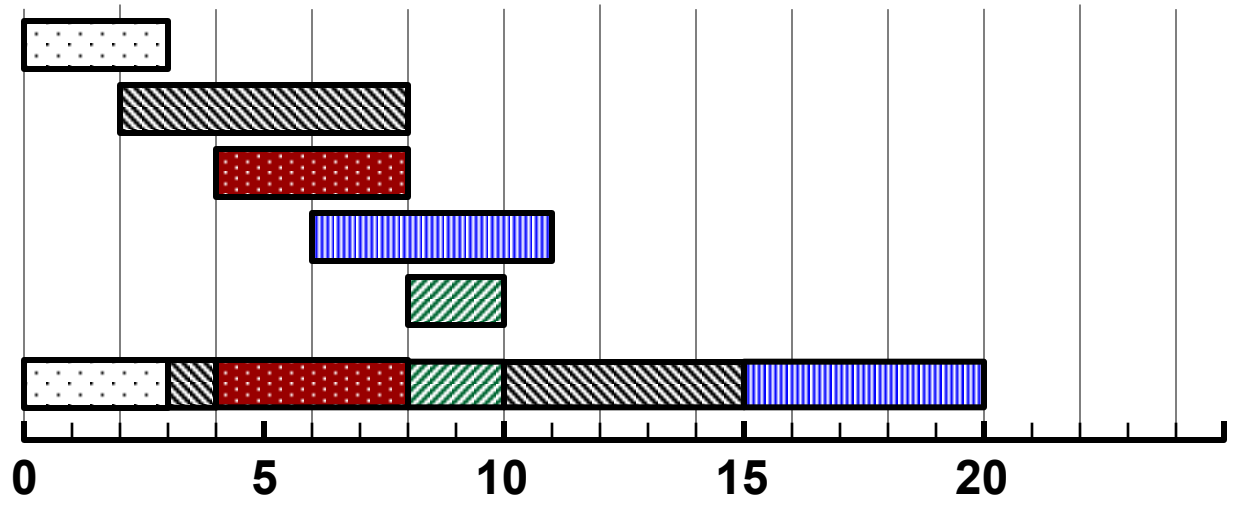
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

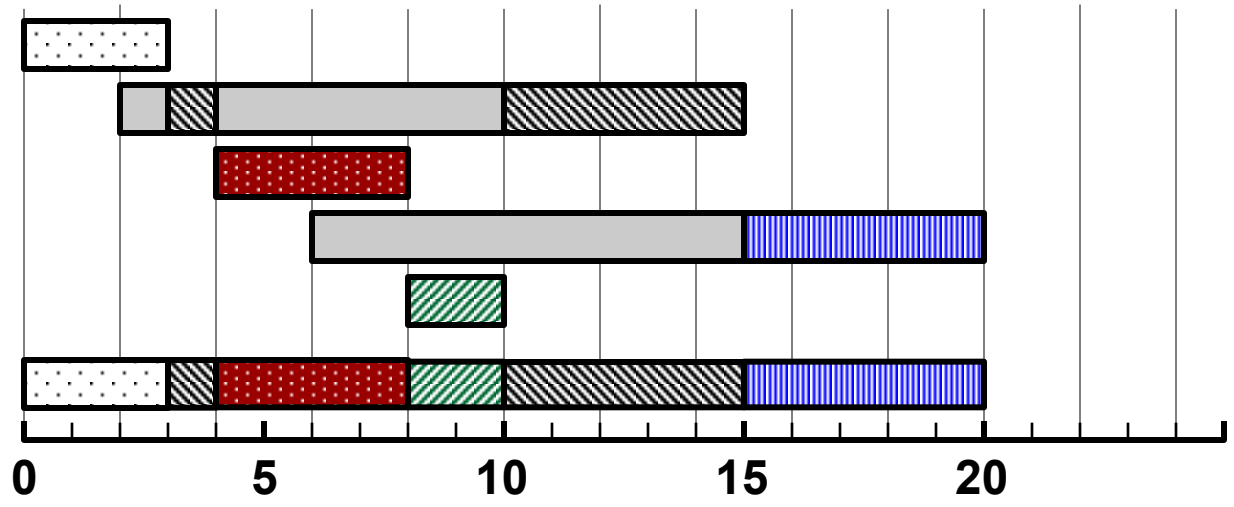
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

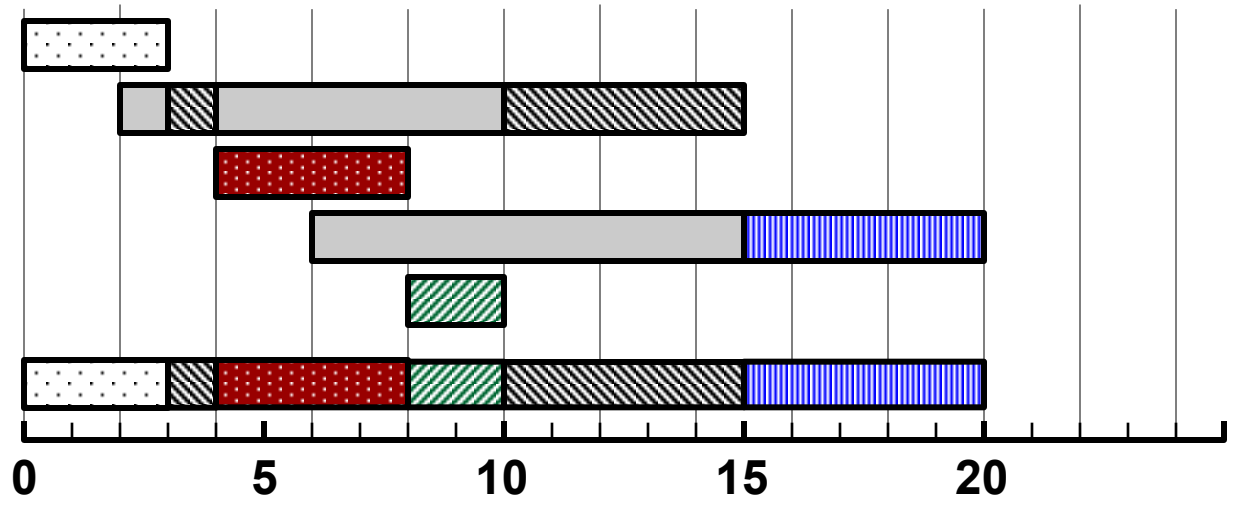
Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3		
2	2	6		
3	4	4		
4	6	5		
5	8	2		



Shortest Remaining Time

- Preemptive version of SJF

Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3	0	
2	2	6	7	
3	4	4	0	
4	6	5	9	
5	8	2	0	



Shortest Remaining Time

- Preemptive version of SJF

Process	Arrival Time	Processing Time	Delay	Turnaround Time
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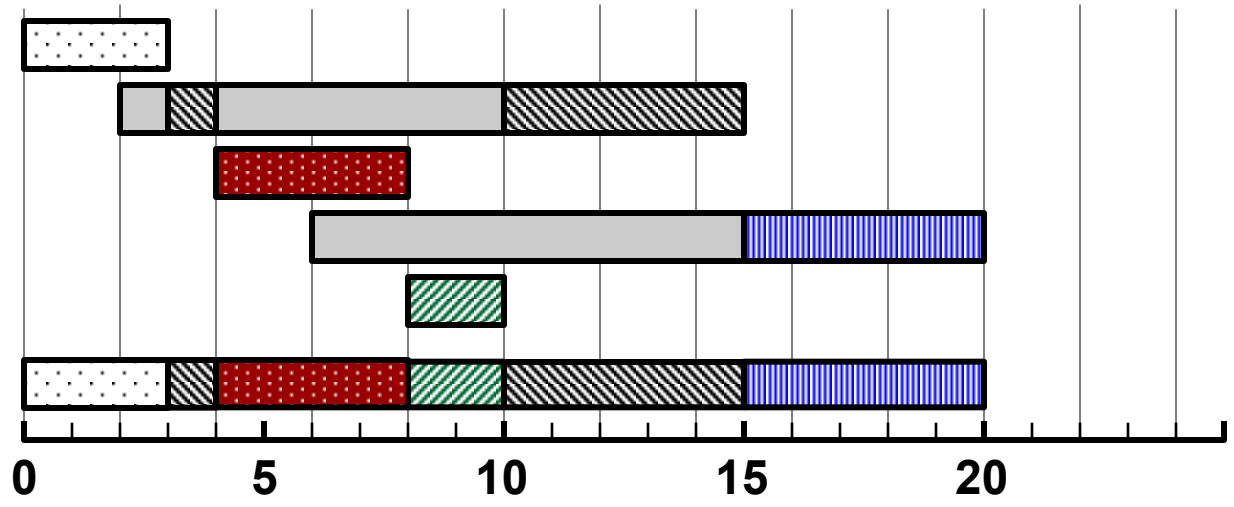
2	2	6	7	13
3	4	4	0	4
4	6	5	9	14
5	8	2	0	2



Round-Robin Scheduling

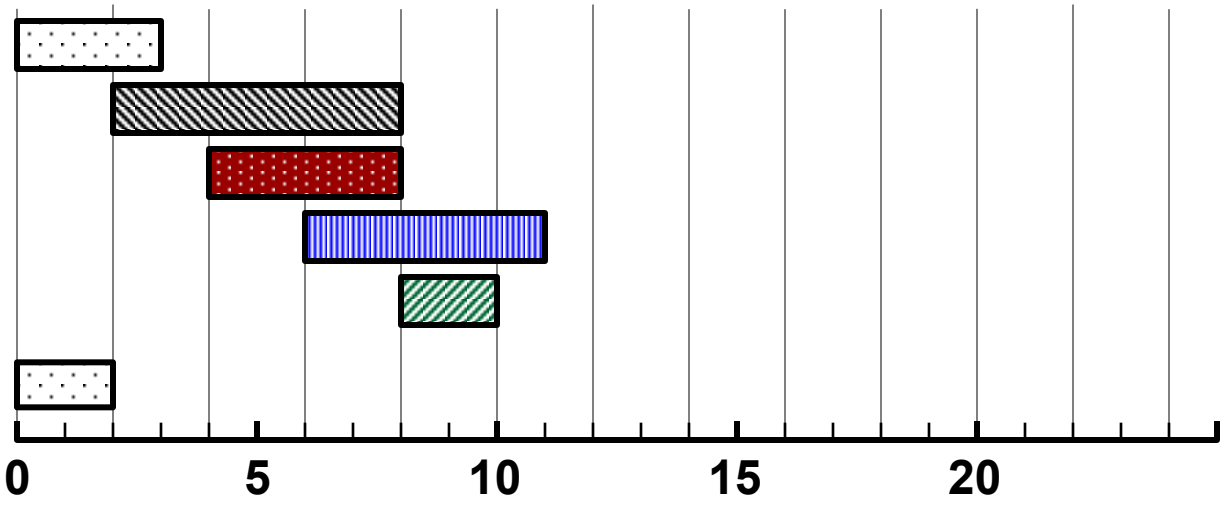
- **Goal:** Enable interactivity
  - Limit the amount of CPU that a process can have at one time.

- **Time quantum**
  - Amount of time the OS gives a process before intervention
  - The "time slice"
  - Typically: 1 to 100ms

Round-Robin Scheduling

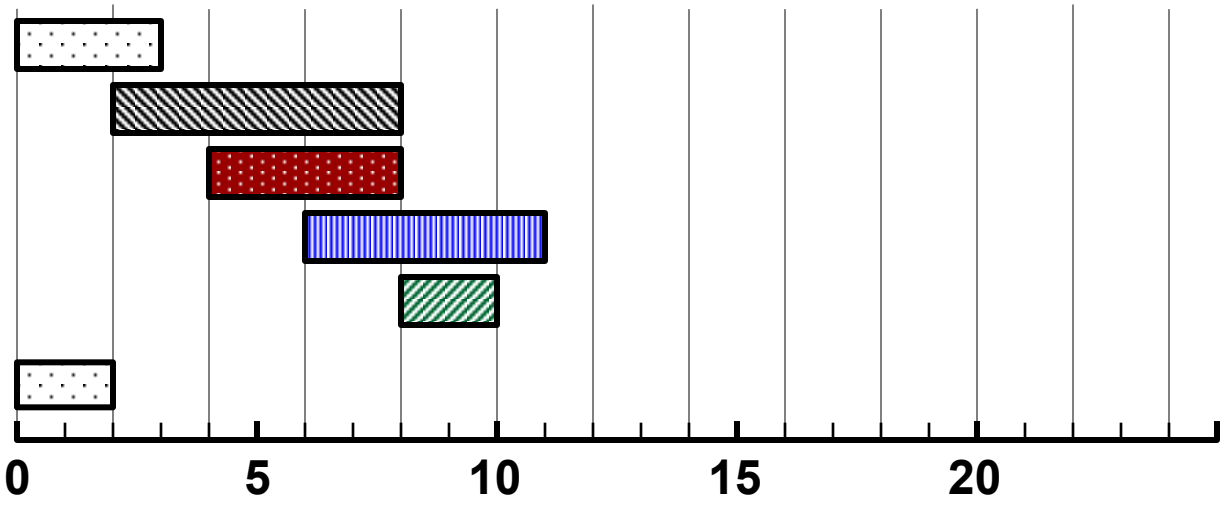
-

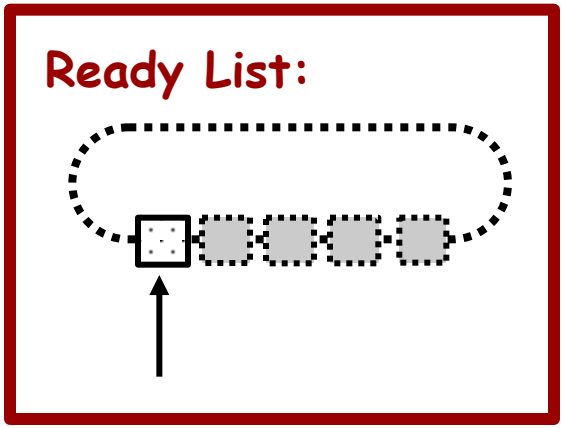
Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2



Round-Robin Scheduling

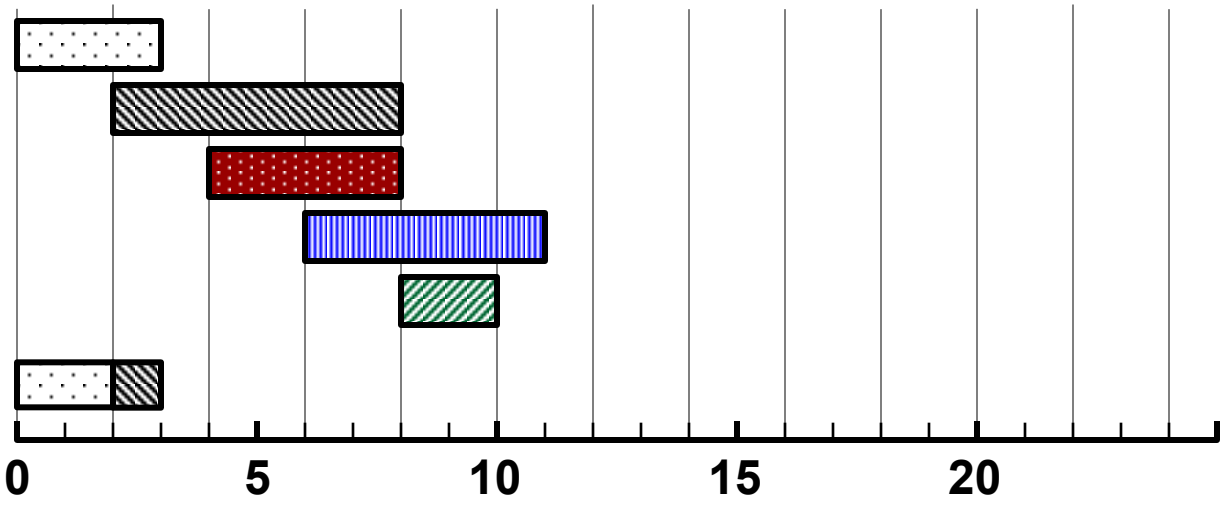
Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2

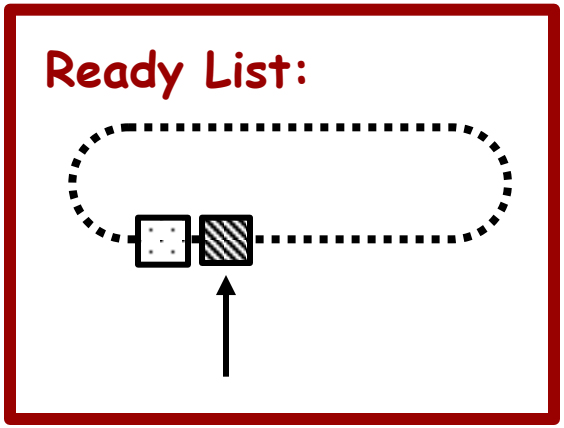




Round-Robin Scheduling

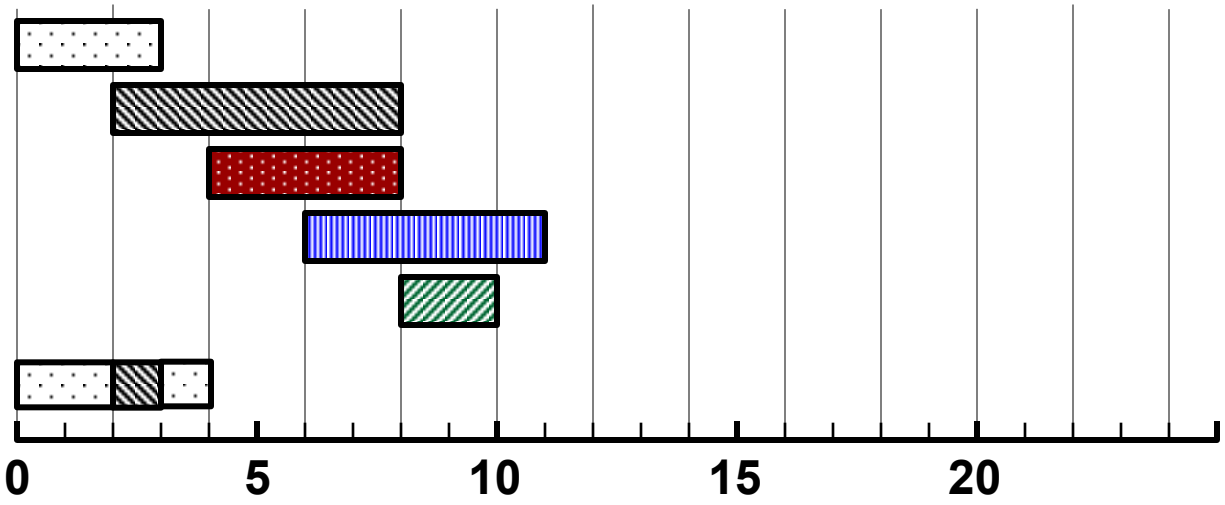
Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2

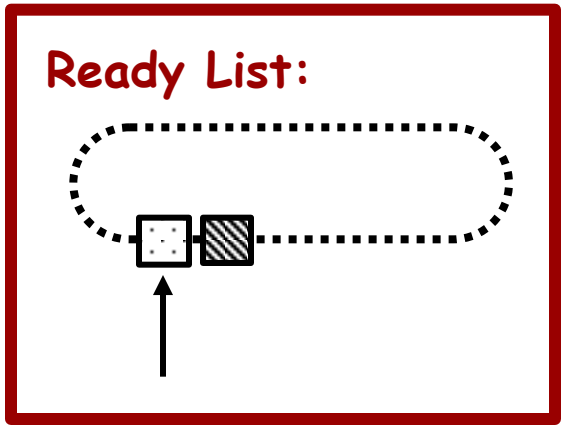




Round-Robin Scheduling

Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

Process	Arrival Time	Processing Time
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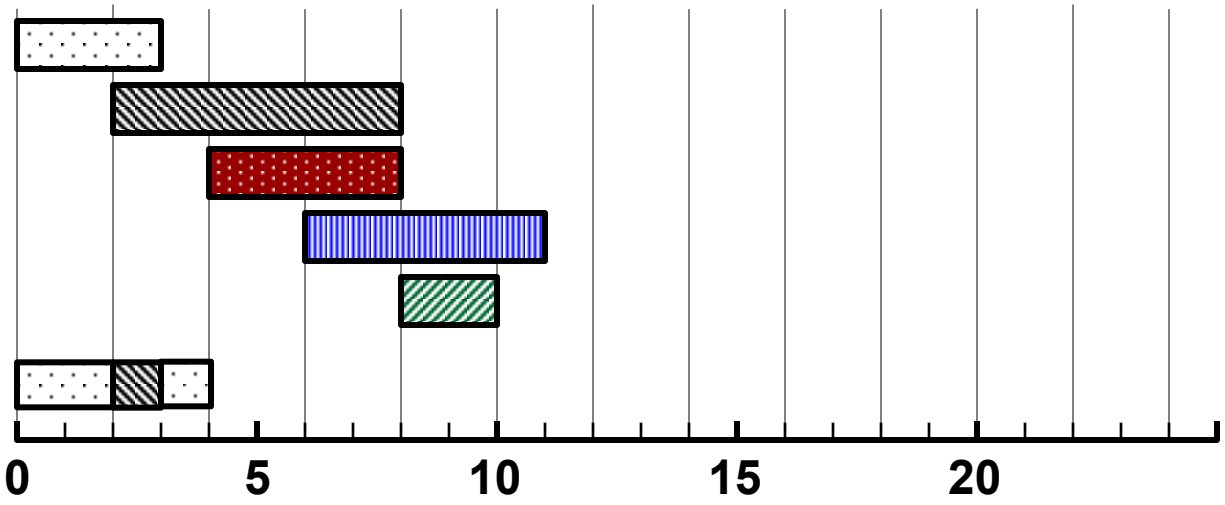
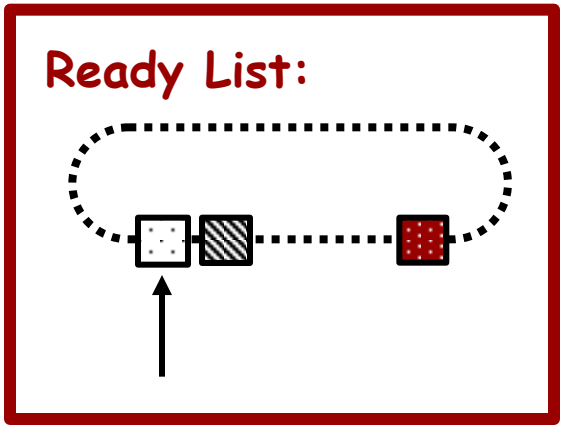
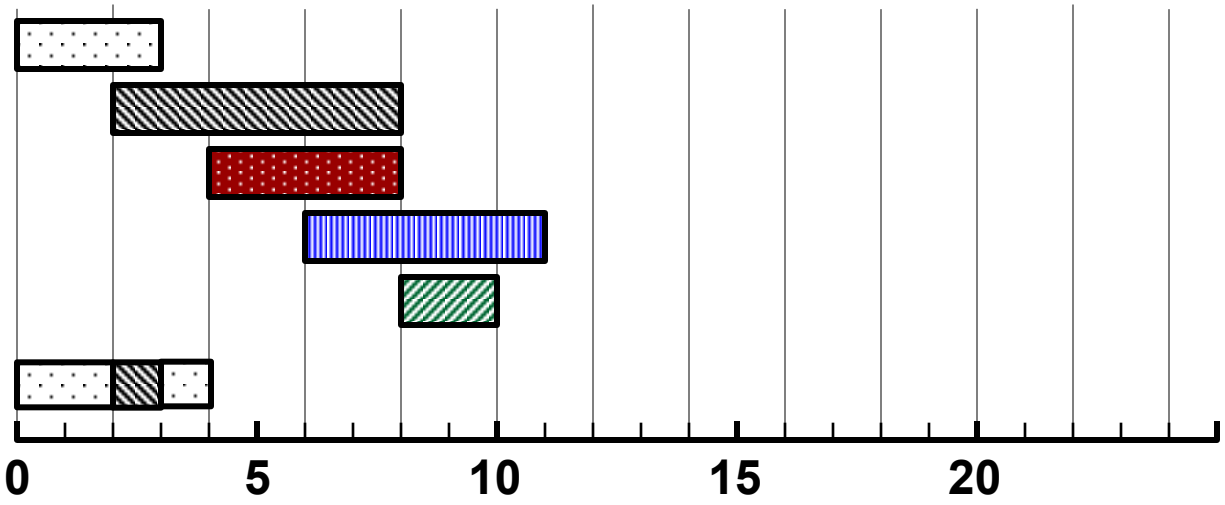
2	2	6
3	4	4
4	6	5
5	8	2

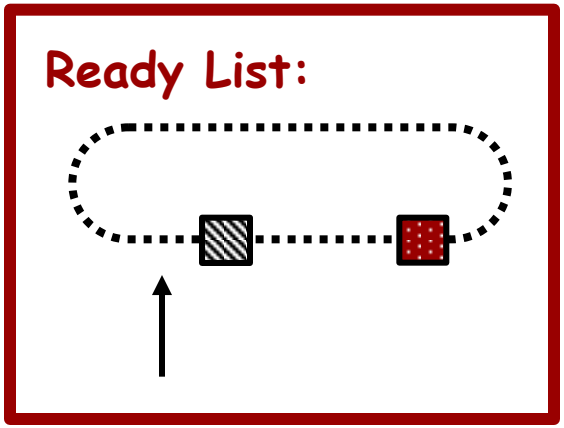




Round-Robin Scheduling

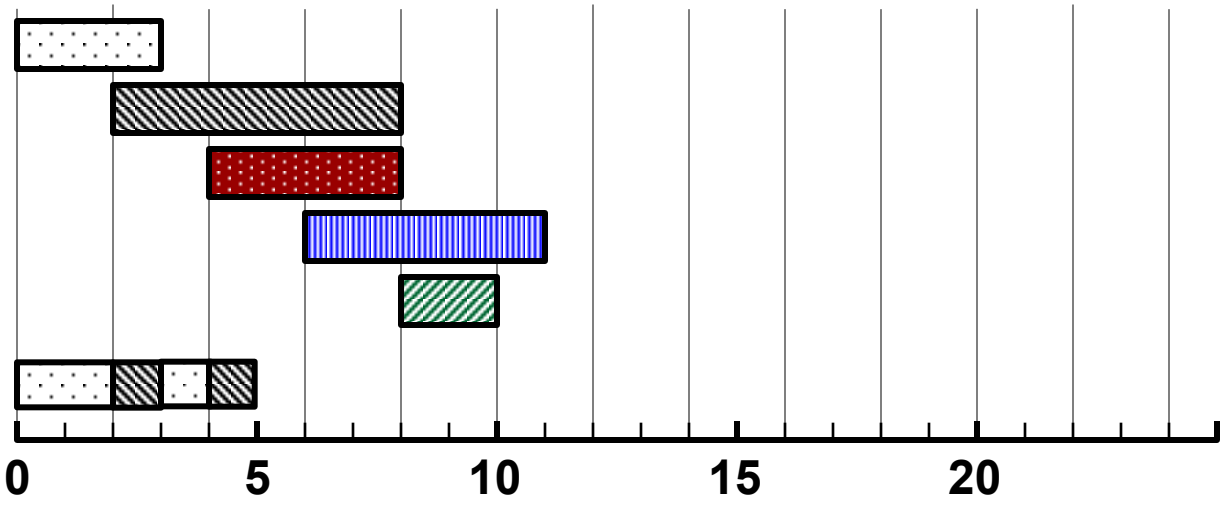
Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2

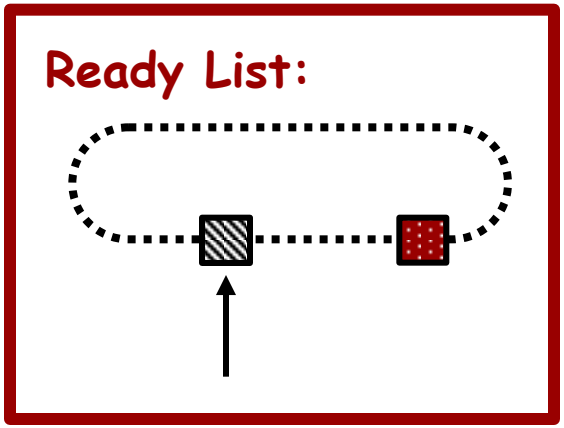




Round-Robin Scheduling

Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

Process	Arrival Time	Processing Time
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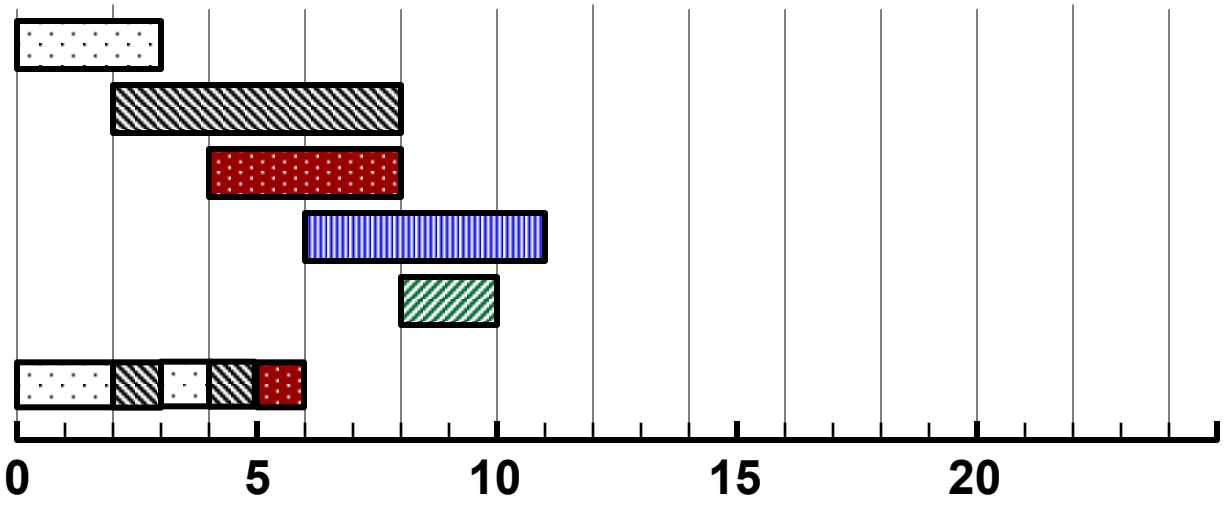
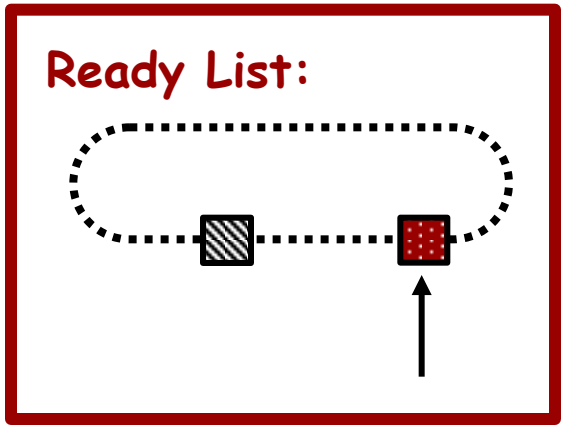
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

Process	Arrival Time	Processing Time
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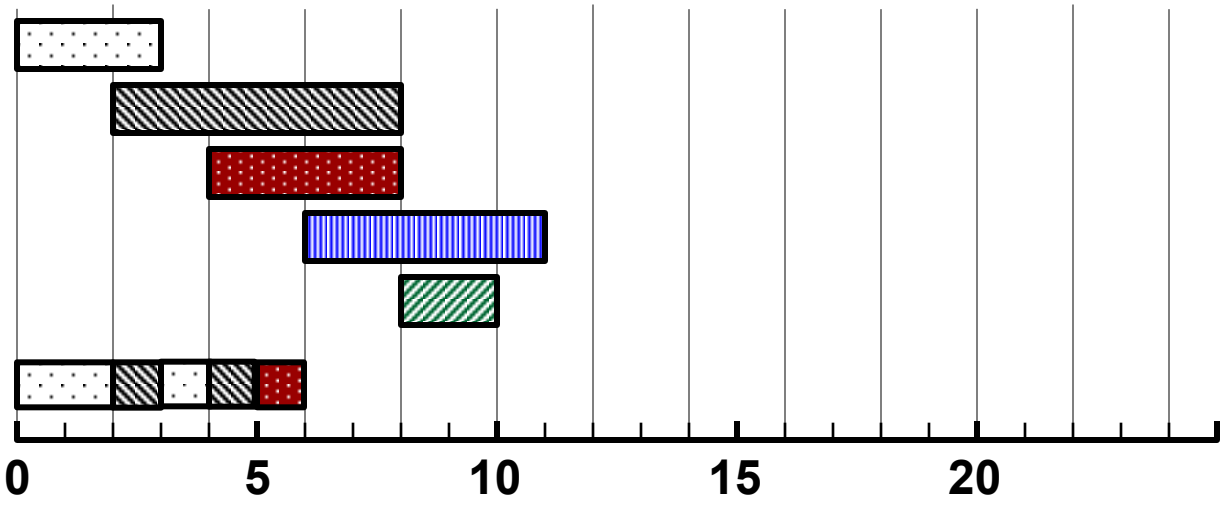
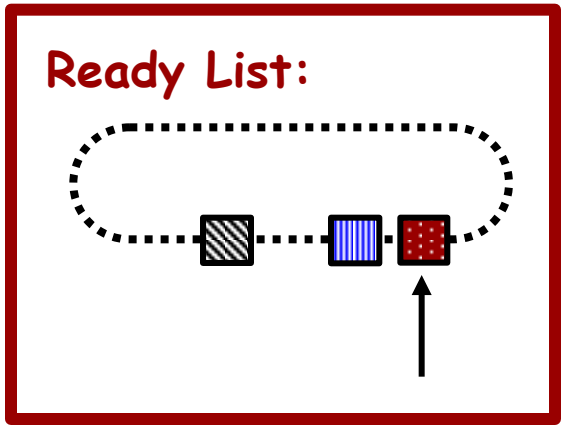
2	2	6
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

Process	Arrival Time	Processing Time
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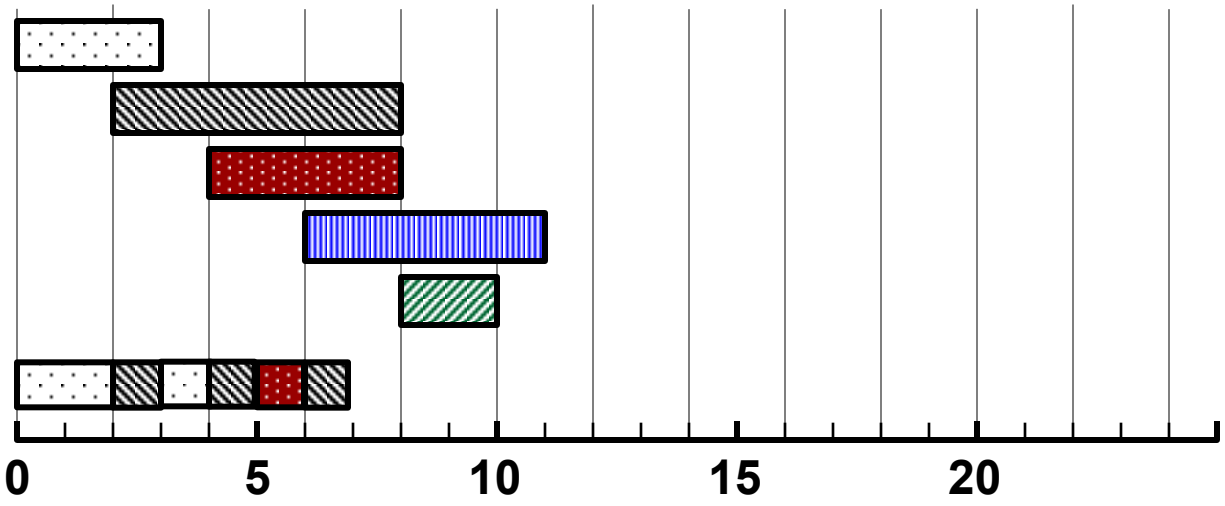
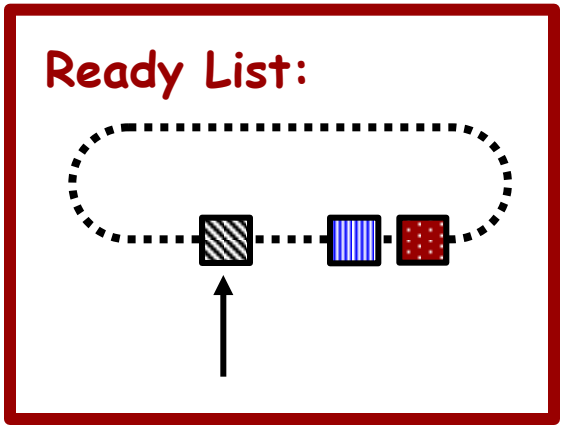
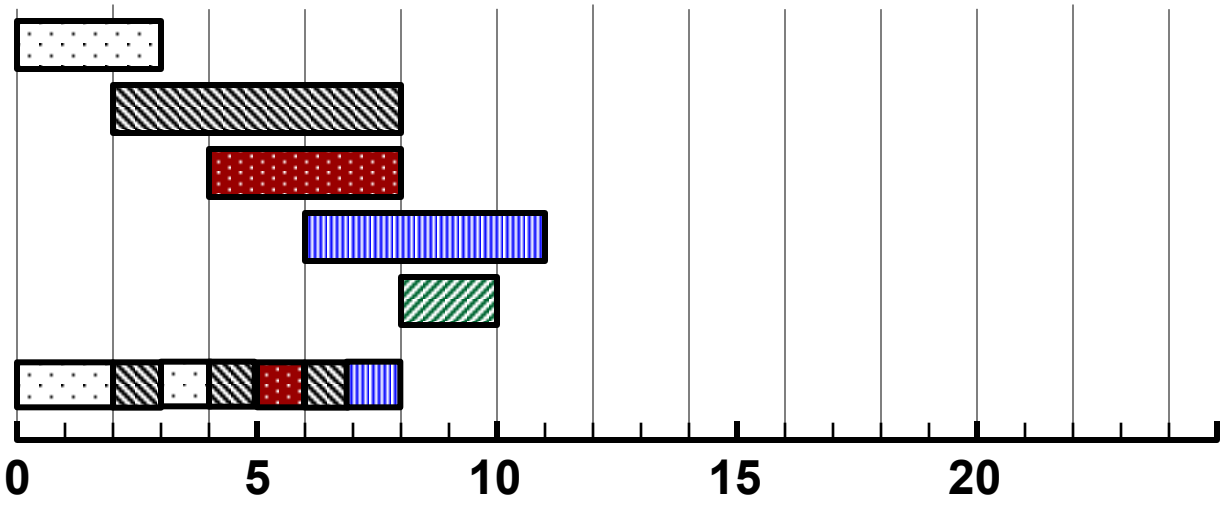
3	4	4
4	6	5
5	8	2

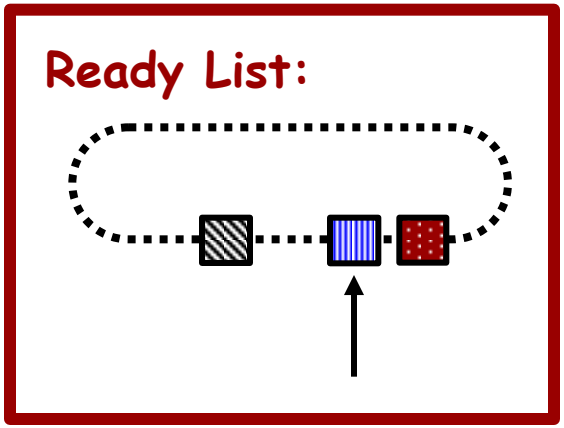




Round-Robin Scheduling

Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

Process	Arrival Time	Processing Time
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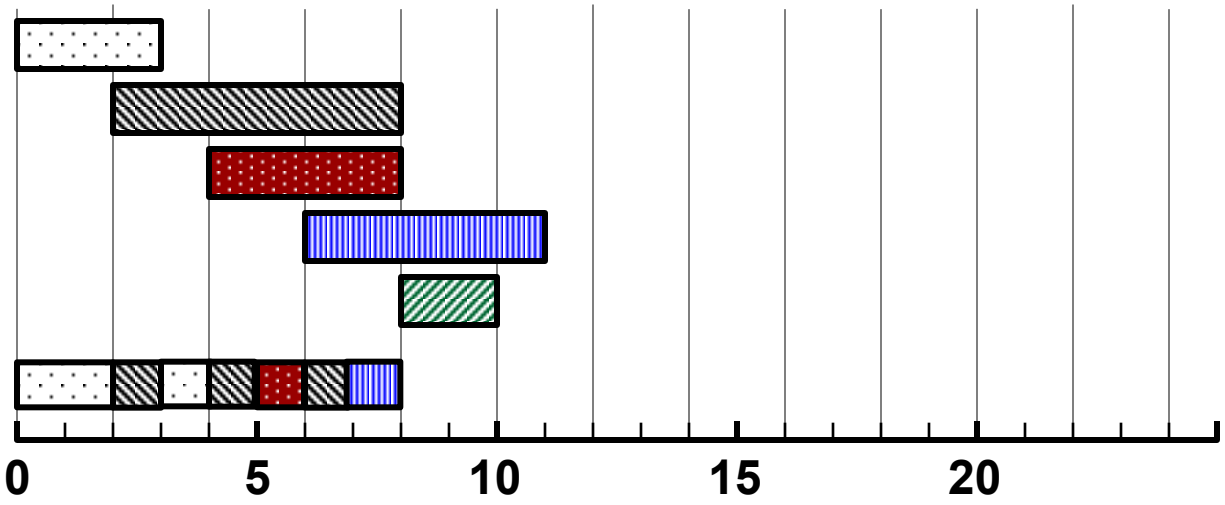
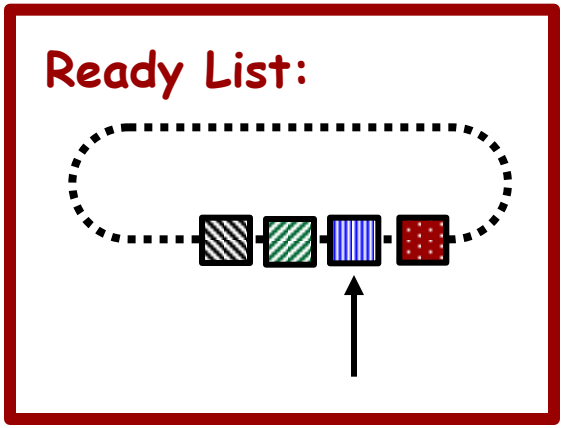
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

Process	Arrival Time	Processing Time
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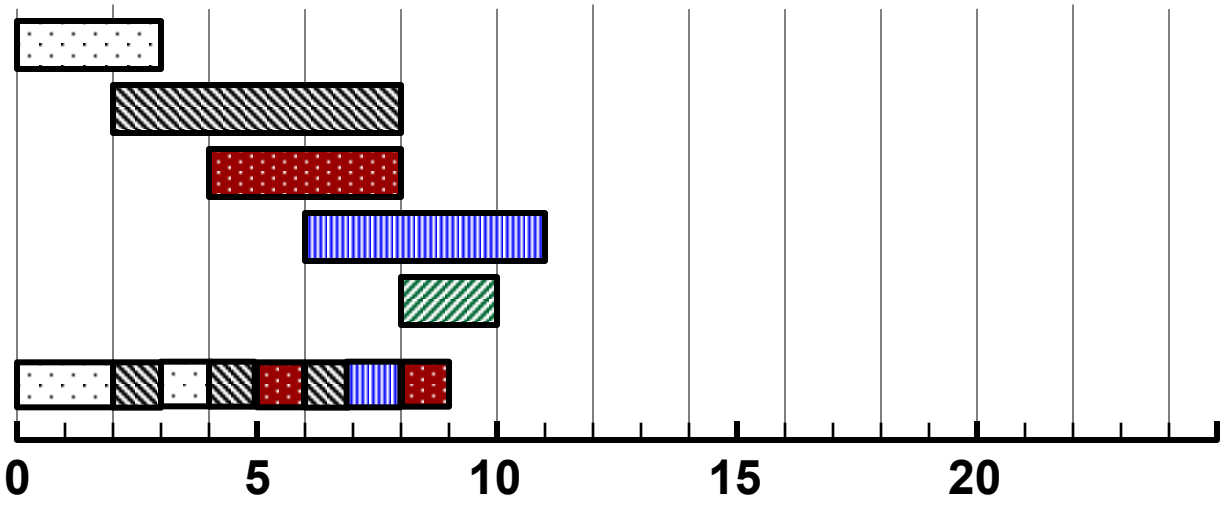
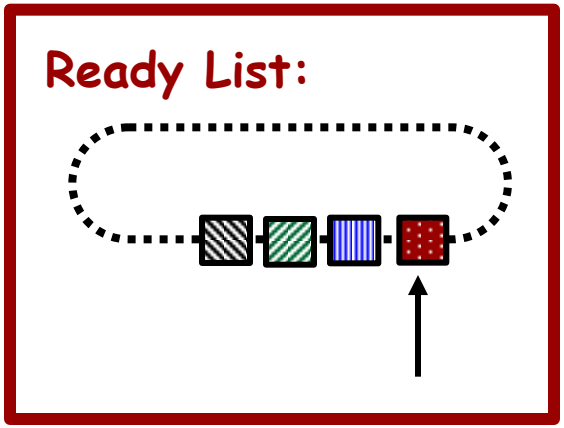
2	2	6
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

Process	Arrival Time	Processing Time
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2	2	6
3	4	4
4	6	5
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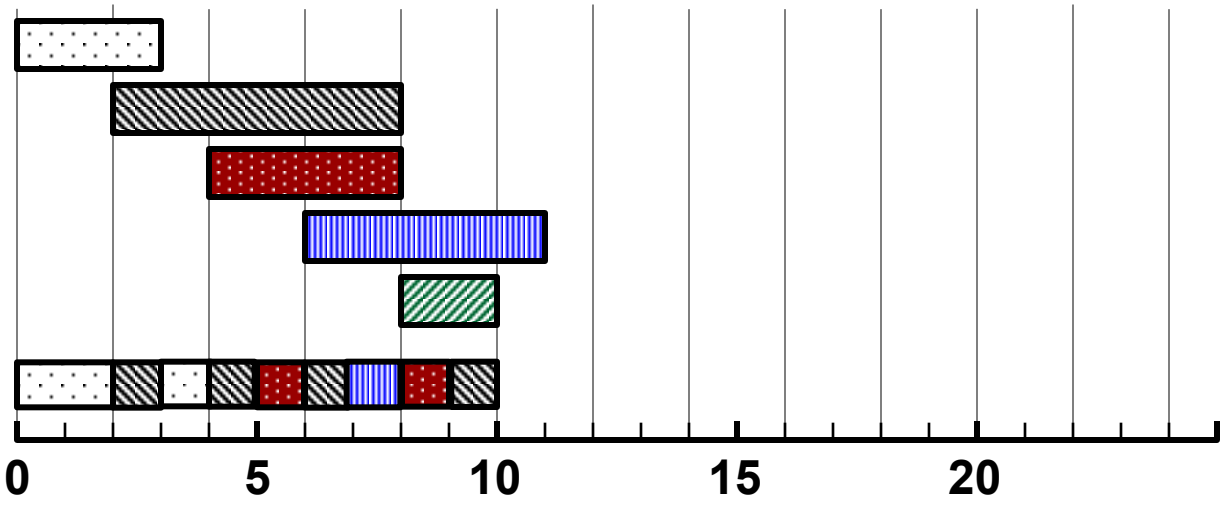

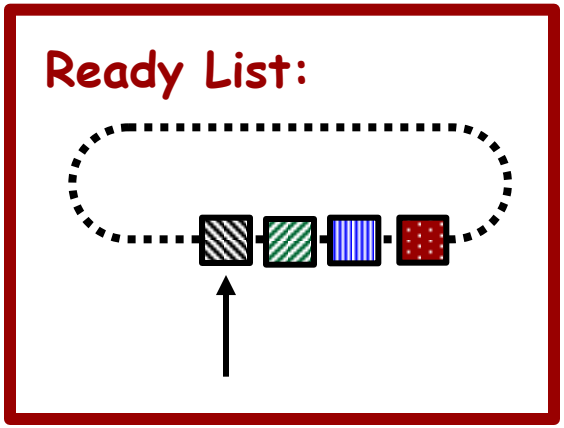

Round-Robin Scheduling

Process	Arrival Time	Processing Time
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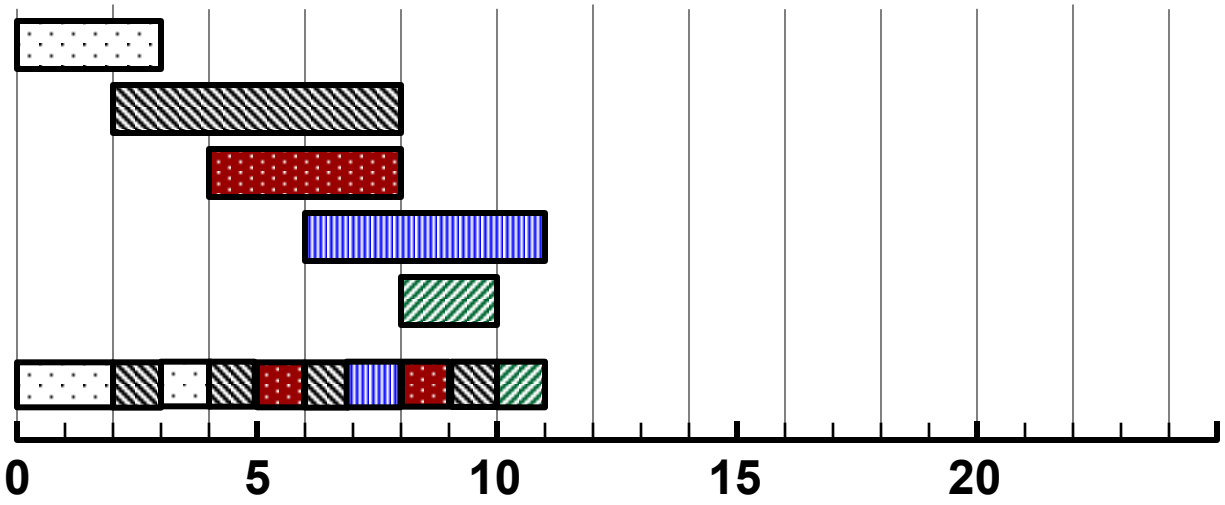
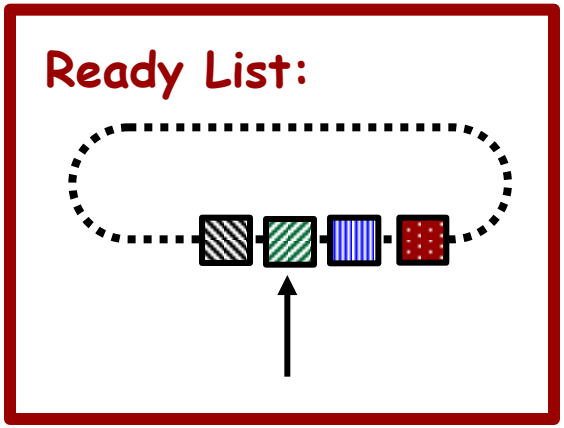
2	2	6
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

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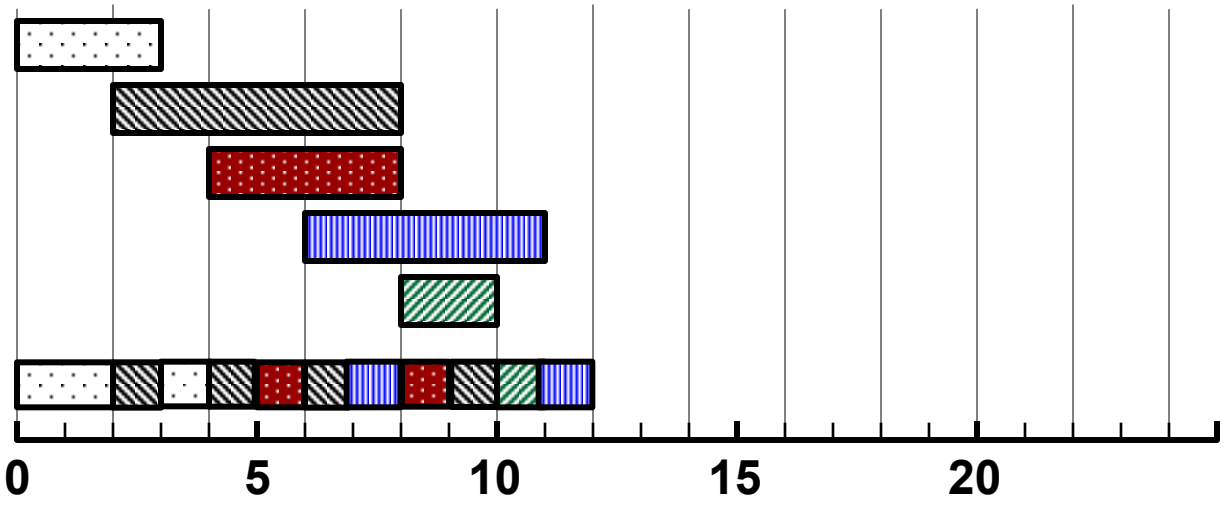
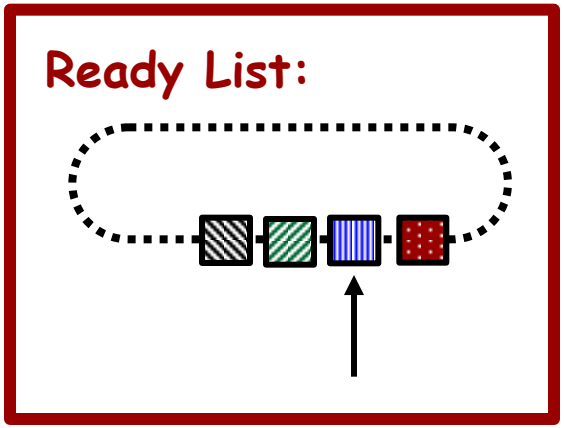
Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2





Round-Robin Scheduling

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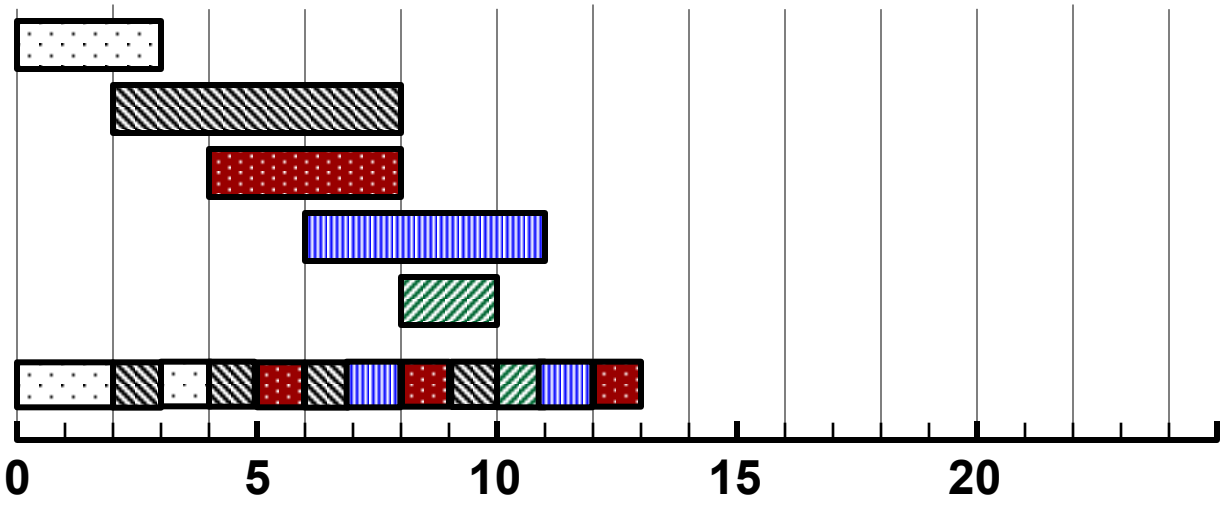
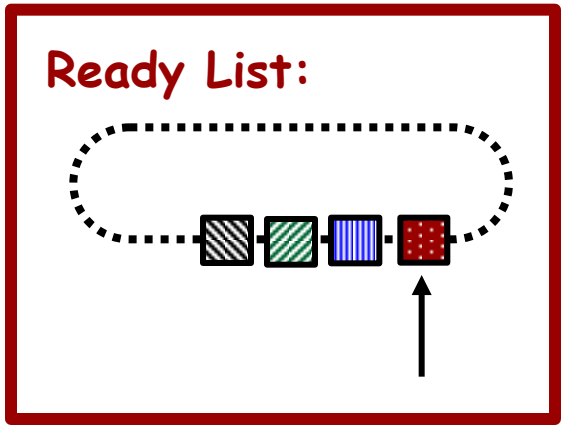
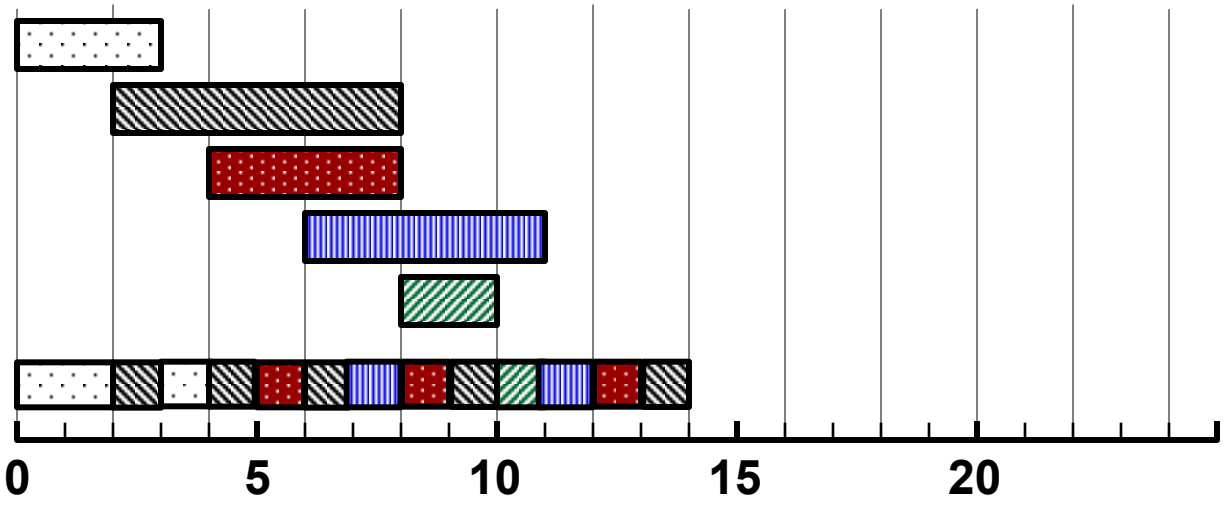
Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2

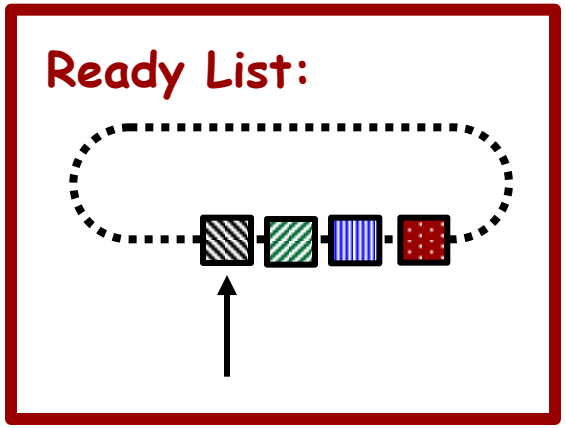




Round-Robin Scheduling

Process	Arrival Time	Processing Time
1	0	3
2	2	6
3	4	4
4	6	5
5	8	2





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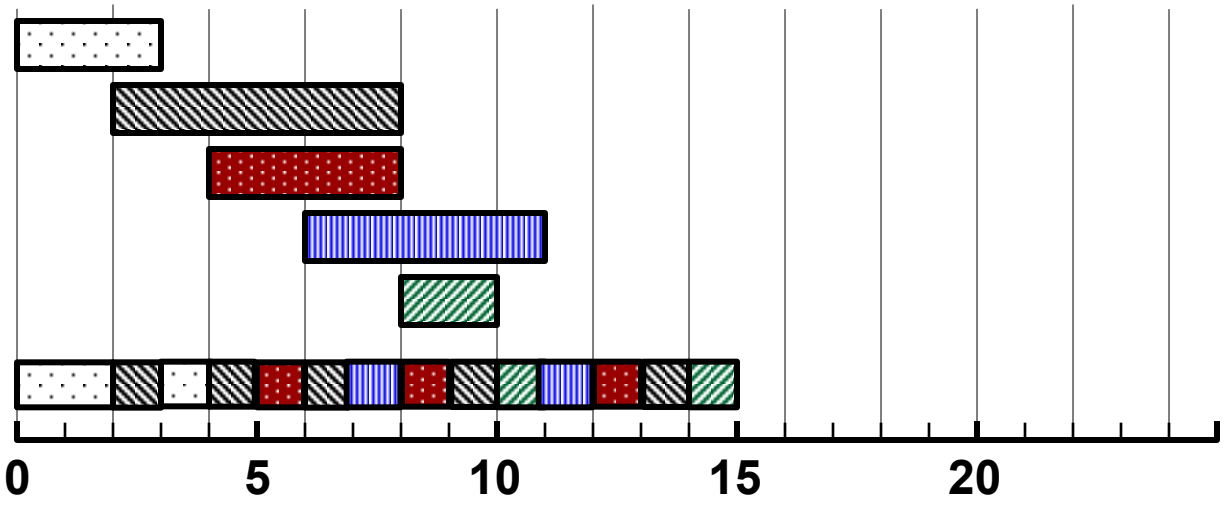

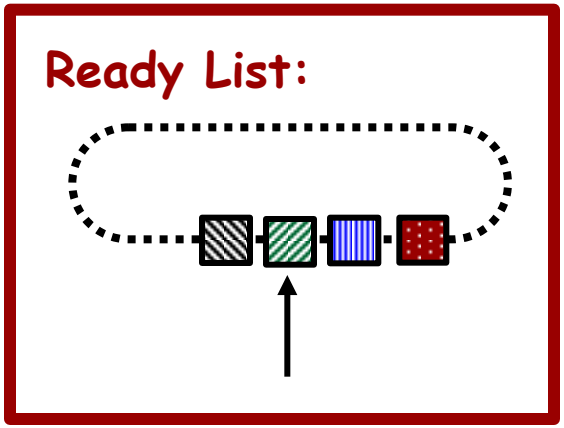

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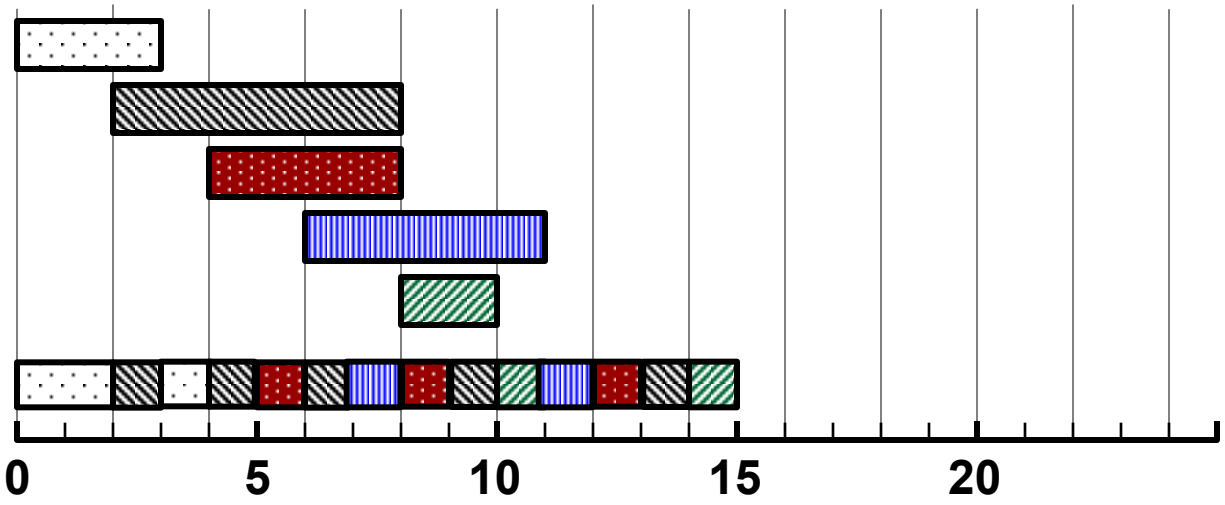

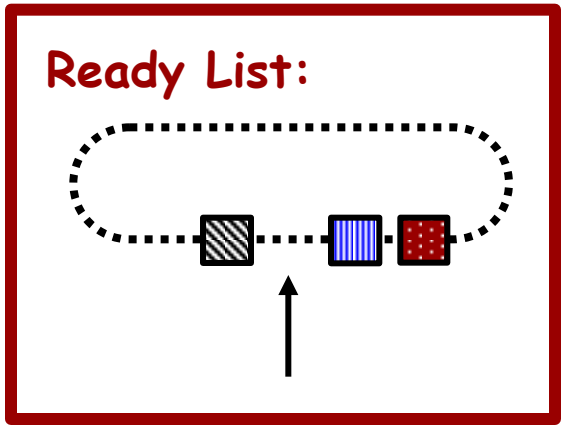

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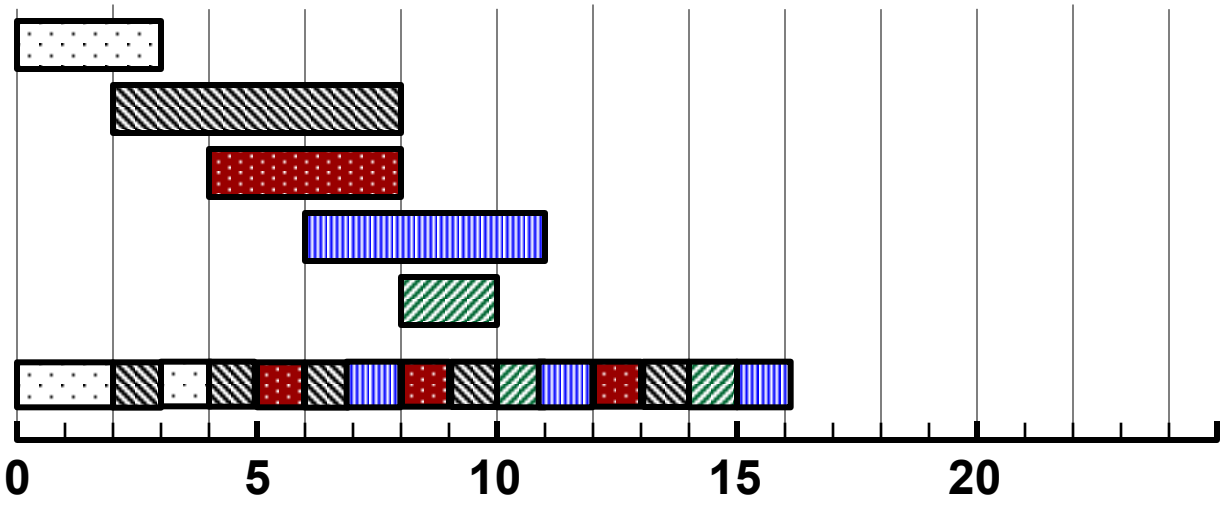

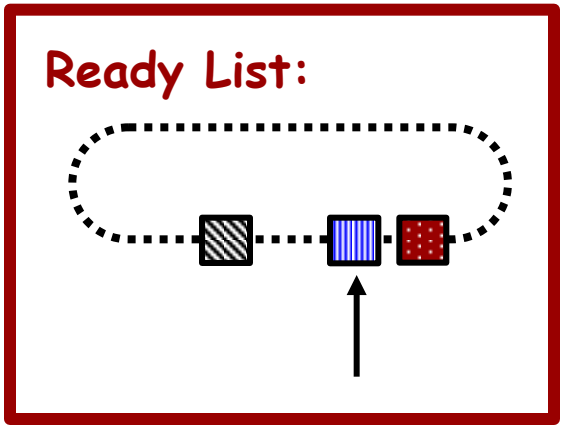

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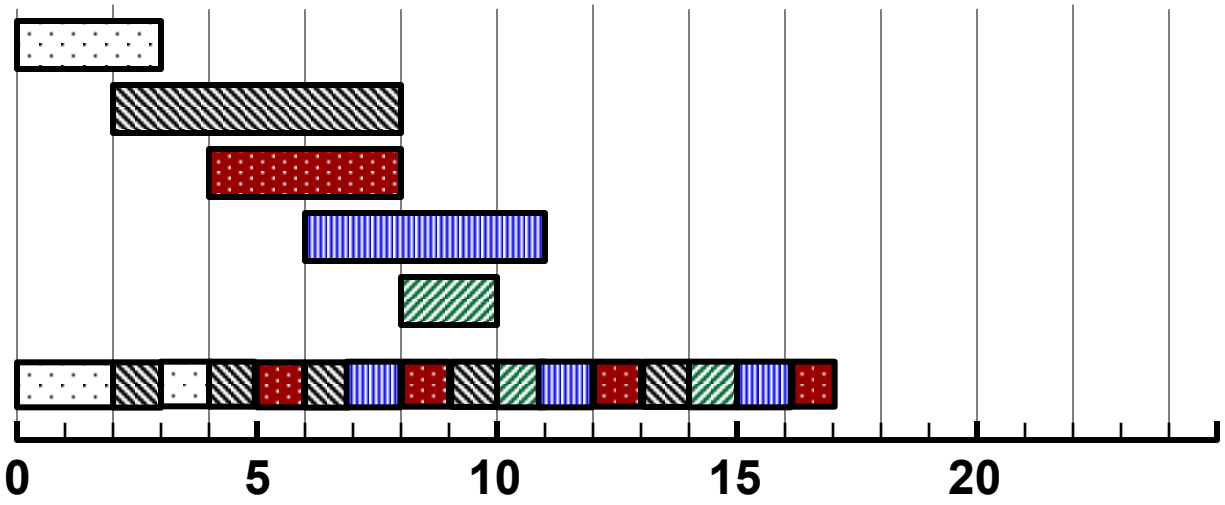

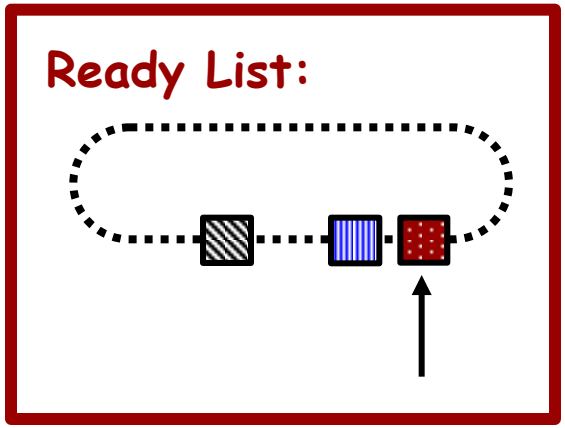

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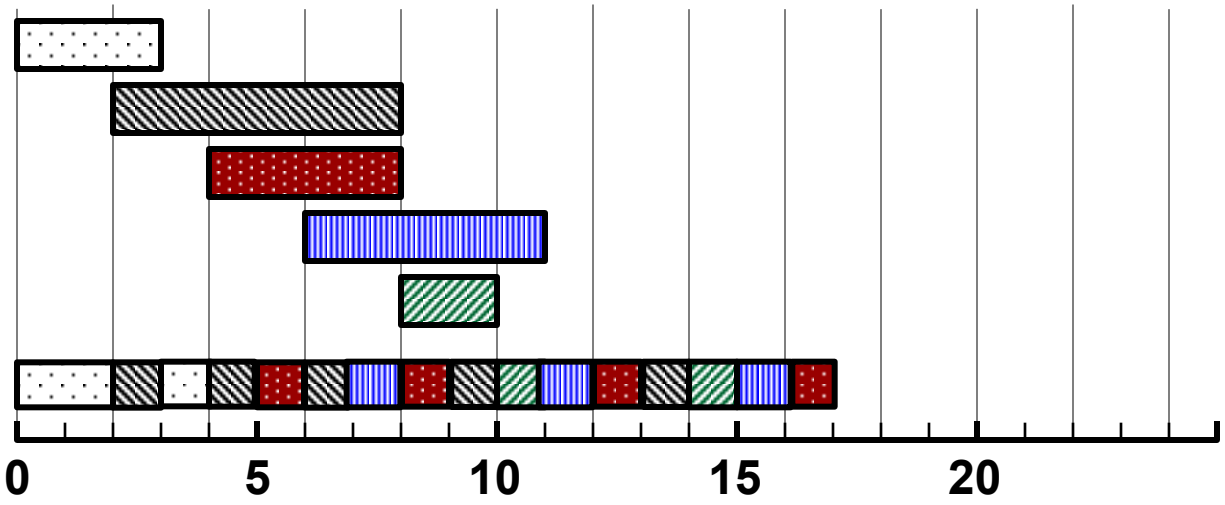

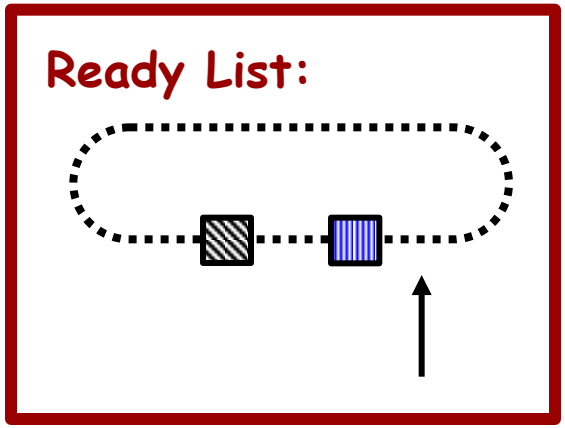

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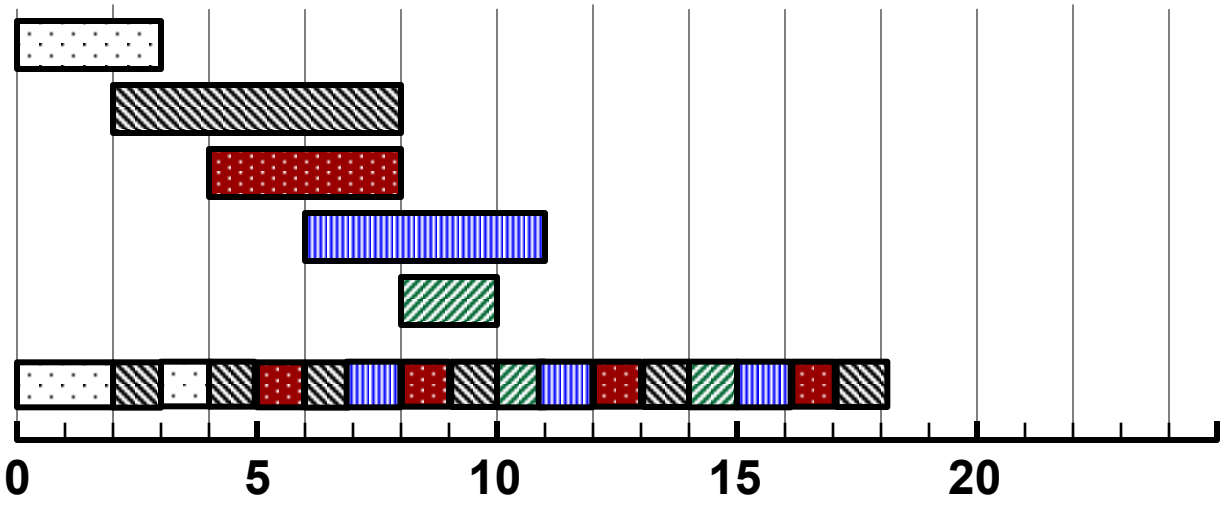

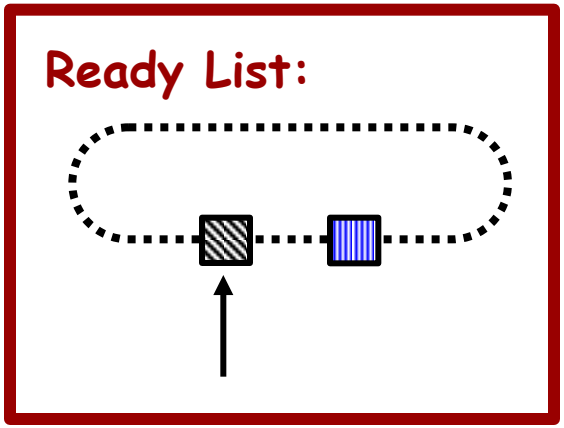

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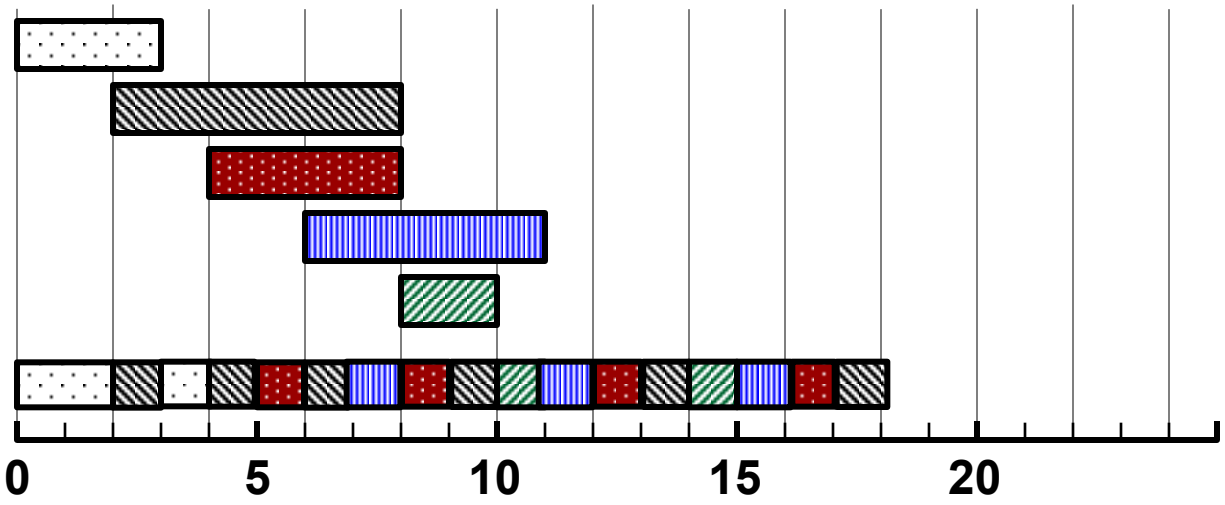

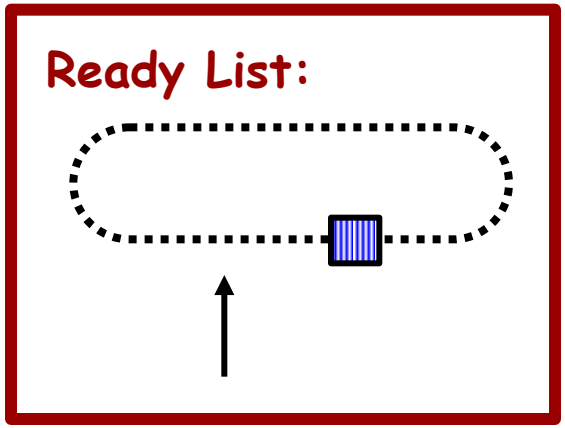

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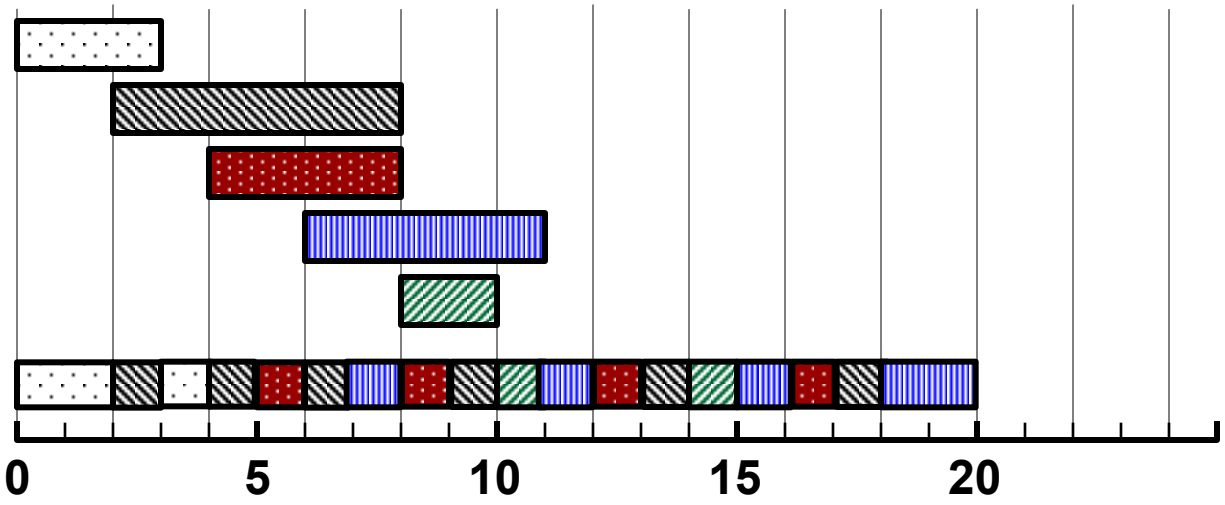

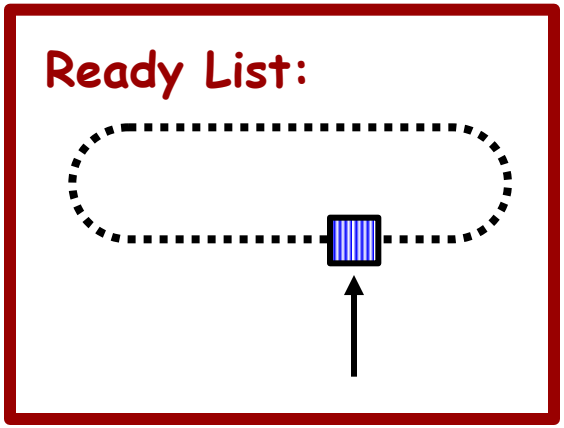

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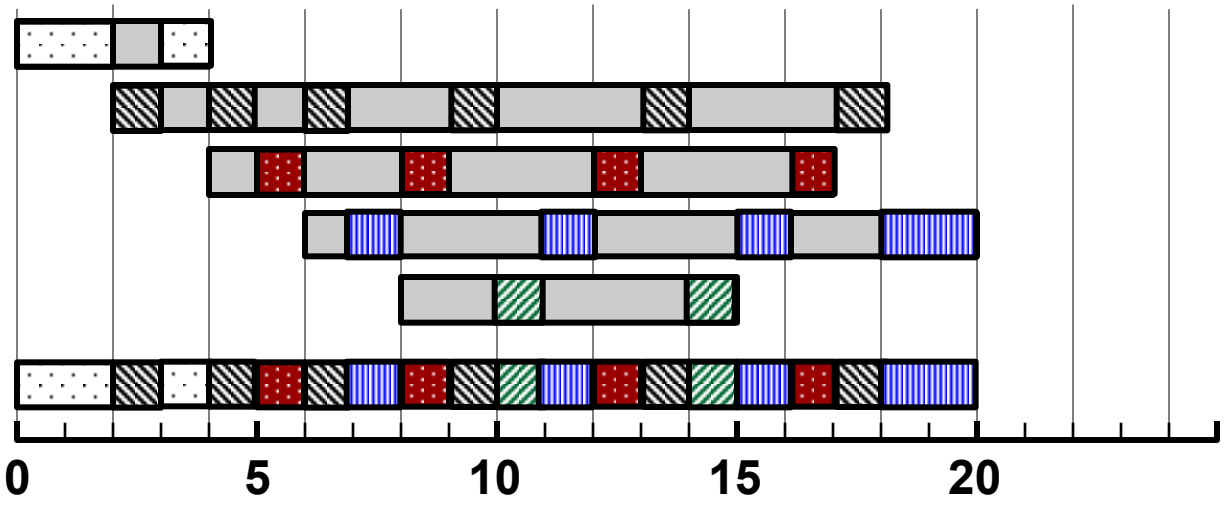
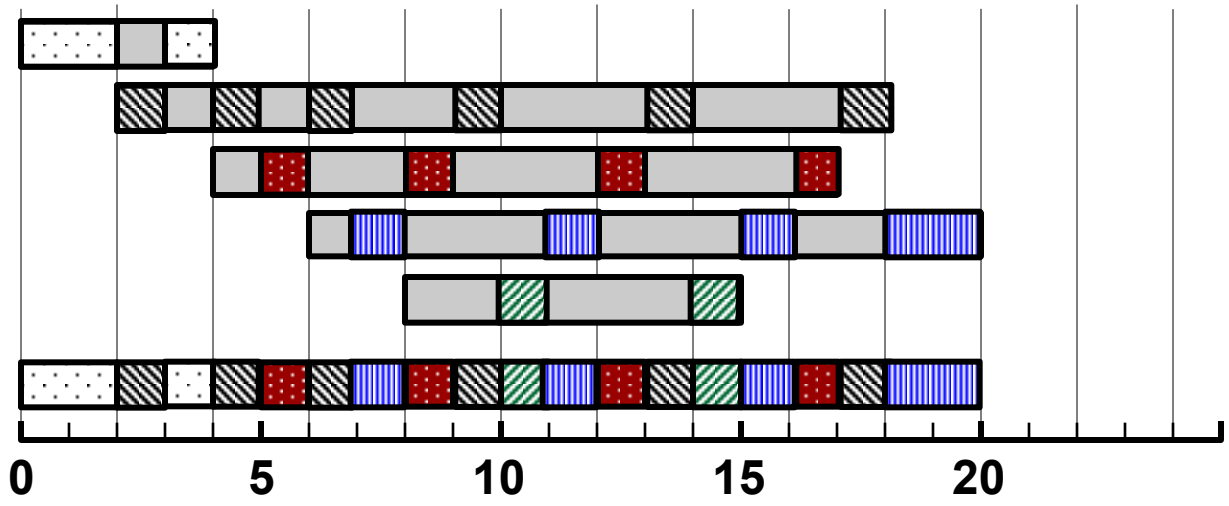


Round-Robin Scheduling

Process	Arrival Time	Processing Time	Delay	Turnaround Time
1	0	3	1	4
2	2	6	10	16
3	4	4	9	13
4	6	5	9	14
5	8	2	5	7



Round-Robin Scheduling

- **Effectiveness of round-robin depends on**
  - The number of jobs, and
  - The size of the time quantum.

- **Large # of jobs means that the time between scheduling of a single job increases**
  - Slow responses

- **Larger time quantum means that the time between the scheduling of a single job also increases**
  - Slow responses

- **Smaller time quantum means higher processing rates but also more overhead!**

Scheduling in general purpose systems

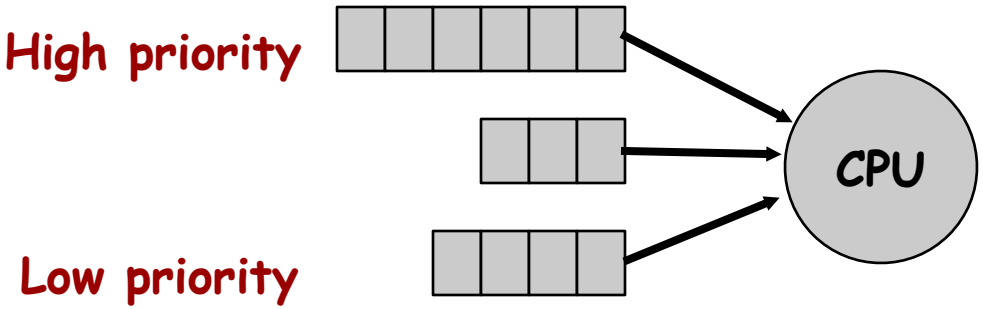
Priority scheduling

- **Assign a priority (number) to each process**
- **Schedule processes based on their priority**
- **Higher priority processes get more CPU time**

- **Managing priorities**
  - Can use "nice" to reduce your priority
  - Can periodically adjust a process' priority
    - **Prevents starvation of a lower priority process**
    - **Can improve performance of I/O-bound processes by basing priority on fraction of last quantum used**

Multi-Level Queue Scheduling

- **Multiple queues, each with its own priority.**
  - Equivalently: each priority level has its own ready queue
- **Within each queue...Round-robin scheduling.**
- **Simplist Approach:**
  - A Process's priority is fixed & unchanging



Multi-Level Feedback Queue Scheduling

- **Problem: Fixed priorities are too restrictive**
  - Processes exhibit varying ratios of CPU to I/O times.
- **Dynamic Priorities**
  - Priorities are altered over time, as process behavior changes!

Multi-Level Feedback Queue Scheduling

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- **Issue: When do you change the priority of a process and how often?**

Multi-Level Feedback Queue Scheduling

- **Problem: Fixed priorities are too restrictive**
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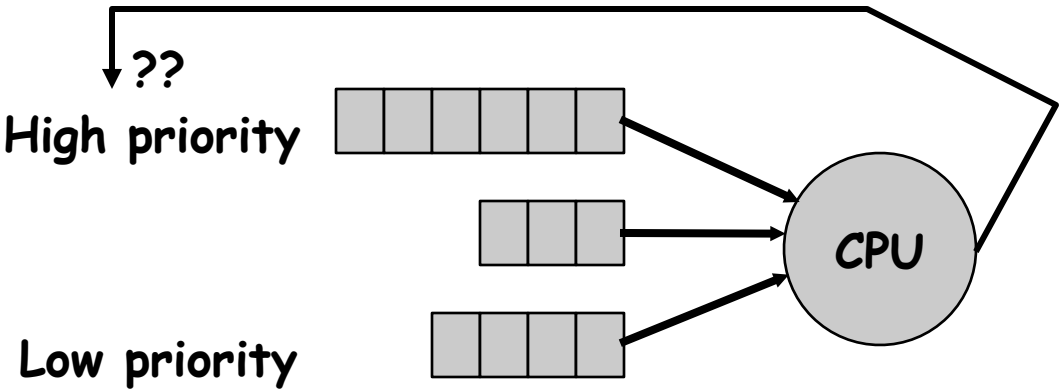
- **Dynamic Priorities**
  - Priorities are altered over time, as process behavior changes!
- **Issue: When do you change the priority of a process and how often?**
- **Solution: Let the amount of CPU used be an indication of how a process is to be handled**
  - Expired time quantum → more processing needed
  - Unexpired time quantum → less processing needed
- **Adjusting quantum and frequency vs. adjusting priority?**

Multi-Level Feedback Queue Scheduling

- n priority levels, round-robin scheduling within a level
- Quanta increase as priority decreases
- Jobs are demoted to lower priorities if they do not complete within the current quantum



Multi-Level Feedback Queue Scheduling

- **Details, details, details...**
  - Starting priority?
  - Frequency of moving between priorities?
  - How long should the time quantum be?

Lottery Scheduling

- **Scheduler gives each thread some lottery tickets**
- **To select the next process to run...**
  - The scheduler randomly selects a lottery number
  - The winning process gets to run

- Example **Thread A gets 50 tickets**
  Thread B gets 15 tickets
  Thread C gets 35 tickets
  There are 100 tickets outstanding.

Lottery Scheduling

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  Thread A gets 50 tickets → 50% of CPU

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- Example
  - Thread A gets 50 tickets → 50% of CPU
  - Thread B gets 15 tickets → 15% of CPU
  - Thread C gets 35 tickets 35% of CPU
  - There are 100 tickets outstanding.
  - Flexible
  - Fair
  - Responsive

A Brief Look at Real-Time Systems

- **Typically real-time systems involve several steps (that aren't in traditional systems)**
- **Admission control**
  - All processes must ask for resources ahead of time.
  - If sufficient resources exist, the job is "admitted" into the system.
- **Resource allocation**
  - Upon admission...
  - the appropriate resources need to be reserved for the task.
- **Resource enforcement**
  - Carry out the resource allocations properly

A Brief Look at Real-Time Systems

- **Assume processes are relatively periodic**
  - Fixed amount of work per period (e.g. sensor systems or multimedia data)
  - Allows for specification of requirements

A Brief Look at Real-Time Systems

- **Two main types of schedulers...**
- **Rate-Monotonic Schedulers**
  - Assign a fixed, unchanging priority to each process based on its requirements specification
  - No dynamic adjustment of priorities
- **Earliest-Deadline-First Schedulers**
  - Assign dynamic priorities based upon deadlines

Rate Monotonic Schedulers

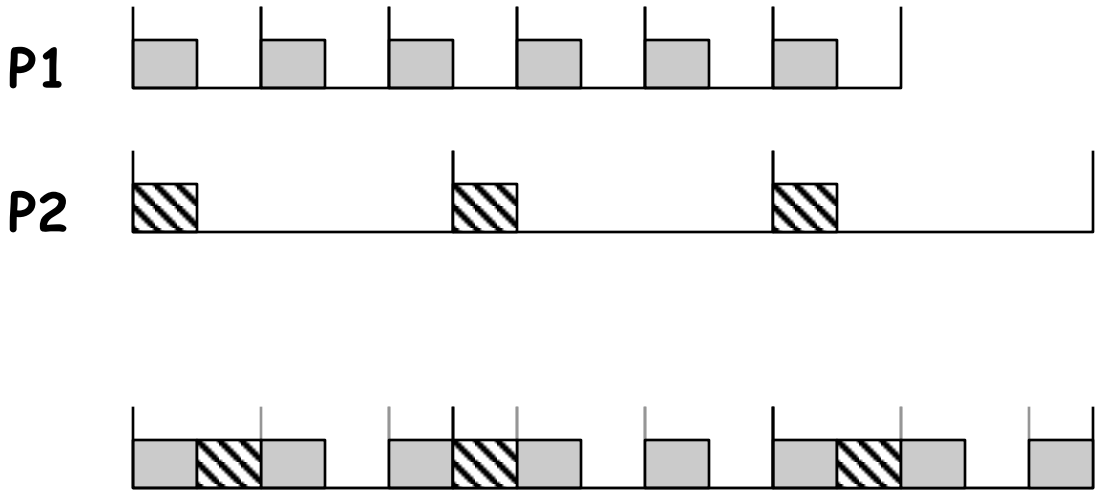
- **For preemptable, periodic processes (tasks)**
- **Assigns a fixed priority to each task**
  - T = The period of the task
  - C = The amount of processing per task period

Process P1

T = 1 second
C = 1/2 second / period

- **In RMS scheduling, the question to answer is...**
  - What priority should be assigned to a given task?

Rate Monotonic Schedulers



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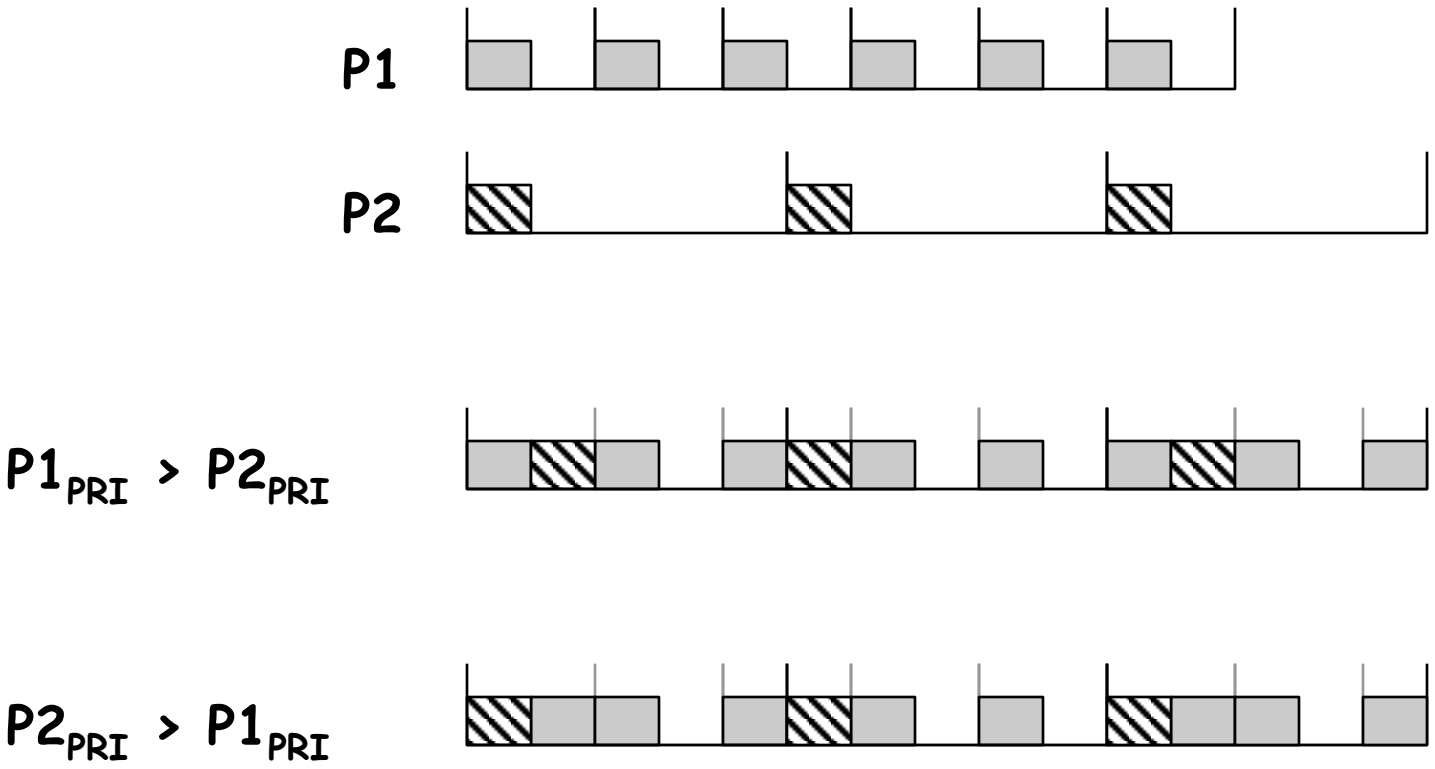

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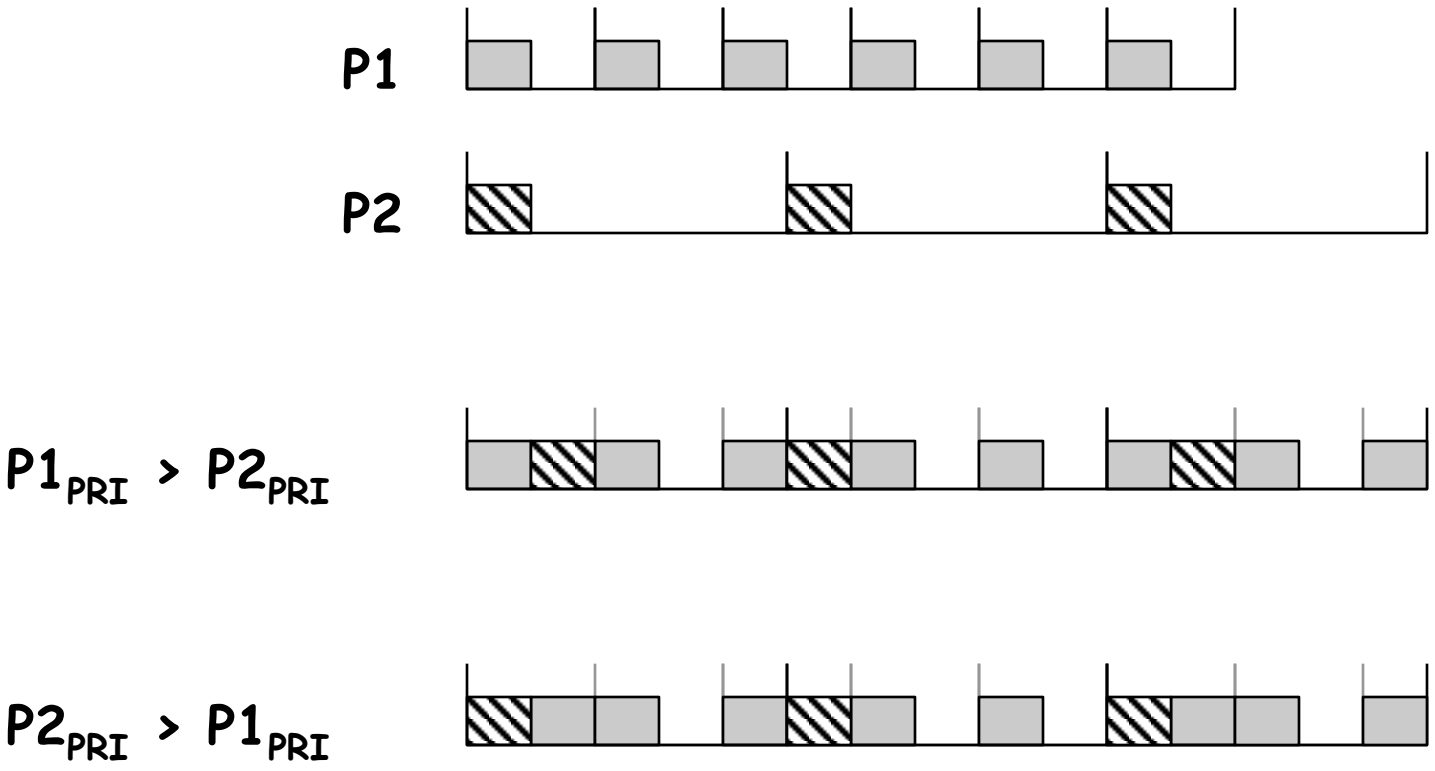

Which is best?

Rate Monotonic Schedulers

- **Assumptions:**
  - Processes complete (yield) within their period
  - Independent processes
  - Same CPU requirements per burst
  - Other non-periodic processes have no deadlines
  - Instantaneous preemption with no overhead

Earliest Deadline First

- **When processes do not have periodic execution or constant CPU requirements...**
- **When processes have deadline specifications...**

- **Unlike RMS, EDF uses dynamic priorities (based upon earliest deadline first)**
  (+) 100% processor utilization
  (-) Need to keep track of deadlines

- **Admission Control**
  - Just check to see if 100% processor utilization.
  - Sum the C_i/T_i's and see if less than or equal to 1
  - What about overhead?

Quiz

- **What are the main tasks of the scheduler?**
- **What is the difference between preemptive and non-preemptive scheduling?**
- **What is the advantage of a shorter scheduling quantum?**
- **What is the advantage of a longer scheduling quantum?**
- **Why is feedback scheduling useful for interactive jobs?**
- **Are these scheduling policies subject to starvation?**
  - Shortest Job First scheduling?
  - Round Robin scheduling?
  - First Come First Served scheduling?
  - Priority scheduling?
  - Earliest Deadline First scheduling?