# CS & IT ENGINEERING

## Operating Systems

CPU Scheduling

**Lecture No. 2**

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TOPICS TO BE COVERED

- HRRN
- Priority Scheduling
- Round Robin

Highest Priority

System Processes

Interactive Processes

Interactive editing Processes

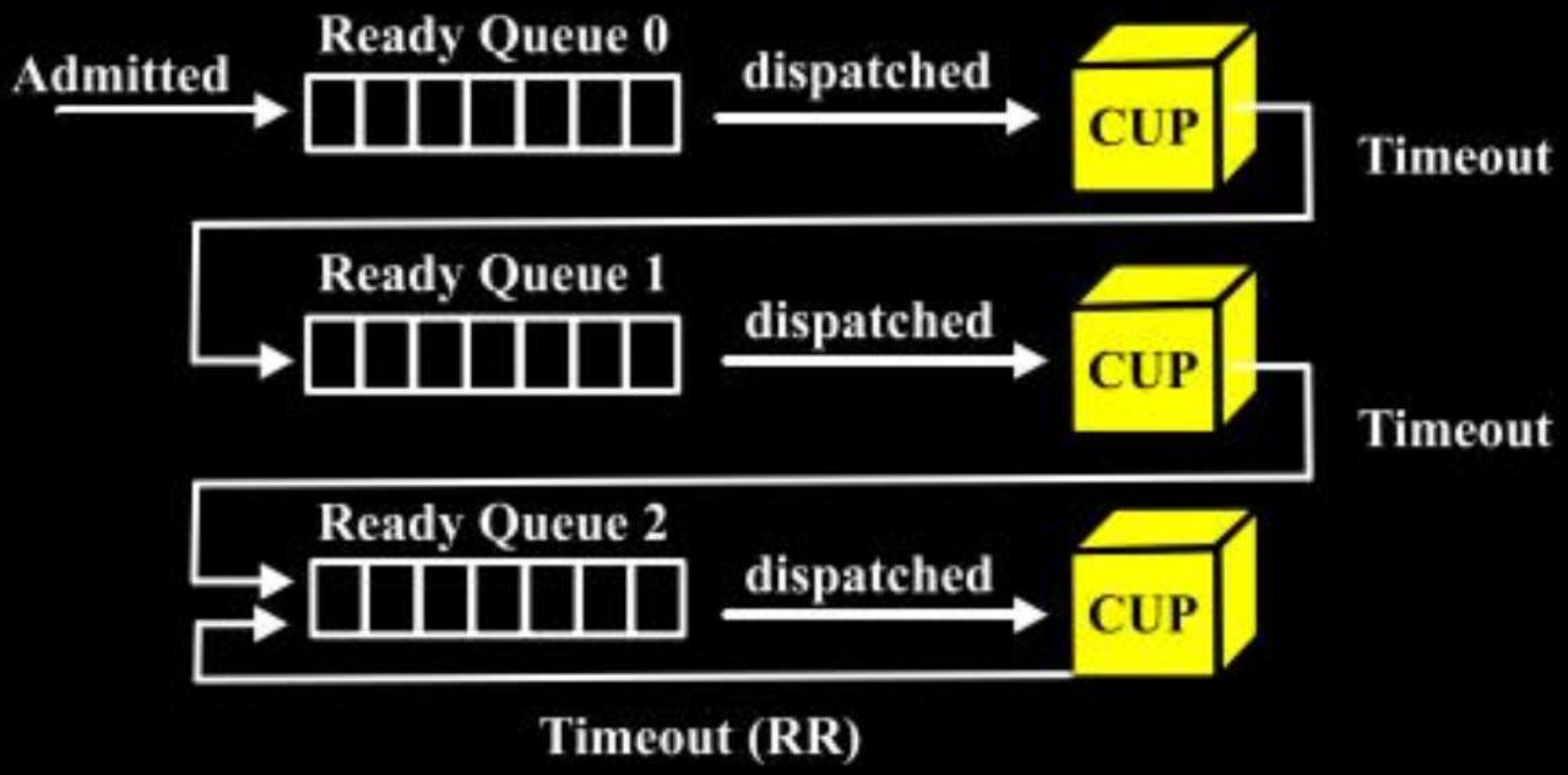
Batch Processes

Student Processes

Highest Priority

# Multilevel feedback Queue Scheduling

- Another way to put a preference on short-lived processes
  - Penalize processes that have been running longer
- Preemptive




Processes in Rq1 are scheduled only when no processes exist in Rq0

Processes in RQ2 are scheduled only when no processes exist in Rq1

Longer processes gradually drift downward

**Q.**

Three Processes arrive at time zero with CPU bursts of 16, 20 and 10 milliseconds. If the scheduler has prior knowledge about the length of the CPU bursts, the minimum achievable average waiting time for these three processes in a Non-Preemptive Scheduler (rounded to nearest integer) is ______ milliseconds.

G

CPU

| $P_3$ | $P_1$ | $P_2$ |
|---|---|---|

0 10 26 46

$$\boxed{\text{Av. W.T} = \frac{10 + 26 + 0}{3} = \frac{36}{3} = 12}$$

# 5) Highest Response Ratio Next (HRRN)

Sel. Criteria : Response Ratio $= \frac{w+s}{s}$ | w = waiting Time of Process so far, s = Service Time (B.T)

Mode of op'n : Non-PreEmptive

"Favors not only Shorter Processes, but also limit the waiting time of longer Process"

| P.No | A.T | B.T |
|---|---|---|
| 1 | 0 | 3 |
| 2 | 2 | 6 |
| 3 | 4 | 4 |
| 4 | 6 | 5 |
| 5 | 8 | 2 |

SJF

Favor Shorter Process

cpu

| $P_1$ | $P_2$ | $P_5$ | $P_3$ | $P_4$ |
|---|---|---|---|---|
| 0–3 | 3–9 | 9–11 | 11–15 | 15–20 |

$t_9$:

$RR_3 = \frac{5+4}{4} = 9/4 = 2.x$ ✓

$RR_4 = \frac{3+5}{5} = 8/5 = 1.6$

$RR_5 = \frac{1+2}{2} = 3/2 = 1.5$

HRRN:

cpu

| $P_1$ | $P_2$ | $P_3$ | $P_5$ | $P_4$ |
|---|---|---|---|---|
| 0–3 | 3–9 | 9–13 | 13–15 | 15–20 |

Favored longer Process

Then Shorter Process

$t_{13}$:

$RR_4 = \frac{7+5}{5} = \frac{12}{5} = 2.4$

$RR_5 = \frac{5+2}{2} = \frac{7}{2} = 3.5$ ✓

# 6) Priority based Scheduling

Sel. criteria: Priority

Mode of op'n : N. Pr / Pr

Tie breaking rule : Lower Pid

Priority = (Integer Value) → f(Type, No. of Resources, Size of Process, - -)

Priority: Static, Dynamic

Static: Starvation

Dynamic (changes @ Regular intervals) → Aging Algo

Av. TAT ; Av W.T

| P.No | A.T | B.T | Prio |
|---|---|---|---|
| 1 | 0 | 4 | 6 |
| 2 | 2 | 3 | 10 |
| 3 | 3 | 2 | 8 |
| 4 | 5 | 5 | 15 |

N. Pr – Prio

CPU

| $P_1$ | $P_2$ | $P_4$ | $P_3$ | |
|---|---|---|---|---|

0, 4, 7, 12, 14

$$Av.TAT = \frac{4+5+11+7}{4} = \frac{27}{4} = 6.75$$

$$Av.W.T = \frac{0+2+9+2}{4} = \frac{13}{4} = 3.25$$

CPU

| $P_1$ | $P_2$ | $P_4$ | $P_3$ | $P_1$ | |
|---|---|---|---|---|---|

0, 2, 5, 10, 12, 14

Pr

$$Av.TAT = \frac{14+3+9+5}{4} = \frac{31}{4} = 7.75$$

Q.

*

G

Consider a System with Preemptive Priority based Scheduling with 3 Processes P1, P2, P3 having infinite instances of them. The instances of these Processes arrive at regular intervals of 3, 7 & 20 ms respectively. The priority of the Process instances is the inverse of their periods. Each of the Process instance P1, P2, P3 consumes 1, 2 & 4 ms of CPU time respectively. The 1st instance of each Process is available at 1 ms. What is the Completion time of the 1st instance of Process P3?

13

| Prio | Period | P.No | A.T | B.T | <Instances .... > |
|---|---|---|---|---|---|
| H $1/3$ | 3 | 1 | 1 | 1 | <4, 7, 10, 13, 16, .... |
| $1/7$ | 7 | 2 | 1 | 2 | <8, 15, 22, 29, .... |
| L $1/20$ | 20 | 3 | 1 | 4 | <21, 41, 61, .... |

R.Q : $\cancel{P_{1_1}}$ ; $\cancel{P_{2_1}}$ ; $P_{3_1}$ ; $\cancel{P_{1_2}}$ , $\cancel{P_{1_3}}$ , $\cancel{P_{2_2}}$ $\cancel{P_{1_4}}$

Cpu

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ////// | $P_{1_1}$ | $P_{2_1}$ | $P_{1_2}$ | $P_{3_1}$ | $P_{1_3}$ | $P_{2_2}$ | $P_{1_4}$ | $P_{3_1}$ |
| 0 – 1 | 1 – 2 | 2 – 4 | 4 – 5 | 5 – 7 | 7 – 8 | 8 – 10 | 10 – 11 | 11 – 13 |

Pr (at 7)

# NAT

Consider the set of processes with arrival time (in milliseconds), CPU burst time (in milliseconds), and priority (0 is the highest priority) shown below. None of the processes have I/O burst time.

The average waiting time (in milliseconds) of all the processes using preemptive priority scheduling algorithm is ___

| Process | Arrival Time | Burst Time | Priority |
|---|---|---|---|
| $P_1$ | 0 | 11 | 2 |
| $P_2$ | 5 | 28 | 0 |
| $P_3$ | 12 | 2 | 3 |
| $P_4$ | 2 | 10 | 1 |
| $P_5$ | 9 | 16 | 4 |

CPU

| $P_1$ | $P_4$ | $P_2$ | $P_4$ | $P_1$ | $P_3$ | $P_5$ |
|---|---|---|---|---|---|---|

0 2 5 33 40 49 51 67

Pv Pv

$$\text{Av.W.T} = \frac{38+0+37+28+42}{5}$$

$$= \frac{145}{5} = 29$$

# 7) Round Robin : M.Pr + Time Sharing Systems (like UNIX)

Sel Criteria: AT + Time Quantum (TQ) (PreEmptive FCFS)

Mode of op'n : PreEmptive

Tie breaking : Lower Pid

→ Each Scheduled Process is alloted a Time quantum; within TQ, if the Process completes | Needs IO then will leave cpu, otherwise, it gets PreEmpted;

TQ = 2

Av.TAT =
Av. WT =
Av. R.T =

| P.No | A.T | B.T |
|---|---|---|
| 1 | 0 | 5 |
| 2 | 0 | 4 |
| 3 | 0 | 2 |
| 4 | 0 | 3 |

$$Av.R.T = \frac{0+2+4+6}{4} = \frac{12}{4} = 3$$

R.Q : ~~P1~~ ; ~~P2~~ ; ~~P3~~ ; ~~P4~~ ; ~~P1~~ ; ~~P2~~ ; ~~P4~~ ; ~~P1~~

CPU

| P1 | P2 | P3 | P4 | P1 | P2 | P4 | P1 | |
|---|---|---|---|---|---|---|---|---|

0 2 4 6 8 10 12 13 14

$$Av.TAT = \frac{14+12+6+13}{4} = \frac{45}{4} = 11.25$$

$$Av.W.T = \frac{9+8+4+10}{4} = \frac{31}{4} = 7.75$$

| P.NO | A.T | B.T |
|---|---|---|
| 1 | 0 | 5 |
| 2 | 0 | 4 |
| 3 | 0 | 2 |
| 4 | 0 | 3 |

FCFS

| CPU | $P_1$ | $P_2$ | $P_3$ | $P_4$ |
|---|---|---|---|---|

0 5 9 11 14

$$Av.TAT = \frac{5+9+11+14}{4} = \frac{39}{4} = 9.75$$

$$Av.WT = \frac{0+5+9+11}{4} = \frac{25}{4} = 6.25$$

$$Av.R.T = \frac{0+5+9+11}{4} = \frac{25}{4} = 6.25$$

TQ=2

| P.No | A.T | B.T |
|---|---|---|
| 1 | 0 | 7 |
| 2 | 2 | 4 |
| 3 | 3 | 2 |
| 4 | 9 | 1 |

R.R → Improve Interactiveness ✓

Responsiveness

Av. TAT =

Av. W.T =

Av. R.T =

R.Q: ~~P1~~; ~~P2~~; ~~P1~~; ~~P3~~; ~~P2~~; ~~P1~~; ~~P4~~; ~~P1~~

| Cpu | P1 | P2 | P1 | P3 | P2 | P1 | P4 | P1 |
|---|---|---|---|---|---|---|---|---|
| | 0–2 | 2–4 | 4–6 | 6–8 | 8–10 | 10–12 | 12–13 | 13–14 |

✓

I: FIFO

R.Q: ~~P1~~; ~~P2~~; P1; P3; P2;

| Cpu | P1 | P2 | |
|---|---|---|---|
| | 0–2 | 2–4 | |

✓

$$Av.\ R.T = \frac{0+0+3+3}{4} = \frac{6}{4} = 1.5$$

II: Lower Pid:

R.Q: ~~P1~~; ~~P1~~; ~~P2~~; ~~P3~~; ~~P1~~; ~~P2~~; ~~P4~~; P1;

| Cpu | P1 | P1 | P2 | P3 | P1 | P2 | P4 | P1 |
|---|---|---|---|---|---|---|---|---|
| | 0–2 | 2–4 | 4–6 | 6–8 | 8–10 | 10–12 | 12–13 | 13–14 |

✓

$$Av.\ R.T = \frac{0+2+3+3}{4} = \frac{8}{4} = 2$$

**Q.** Consider a set of 4 Processes A, B, C, D arriving in the order at time $0^+$. Their Burst Time requirements are 4, 1, 8, 1 respectively using Round Robin scheduling with time quantum of 1 unit, The Completion time of Process A is ____.

G

1m

TQ=1

R.Q: ~~A~~, ~~B~~, ~~C~~, ~~D~~, A, C,

CPU

| A | B | C | D | A | C | A | C | A | |
|---|---|---|---|---|---|---|---|---|---|

0 1 2 3 4 5 6 7 8 9

$0^+$

Timer $\boxed{0^+}$

**Q.** Consider a System with ‘n’ Processes arriving at time $0^+$ with substantially large Burst Times. The CPU scheduling overhead is ‘s’ seconds, Time Quantum is ‘q’ seconds. Using Round Robin scheduling, what must be the value of Time Quantum ‘q’ such that each Process is guaranteed to get its turn at the CPU exactly after ‘t’ seconds in its subsequent run-on CPU.

Q. Which of the following statements (s) is/are correct in the context of CPU Scheduling?

(A) The goal is to only maximize CPU utilization and minimize throughput

(B) Turnaround time includes waiting time

(C) Implementing preemptive scheduling needs hardware support

(D) Round-robin policy can be used even when the CPU time required by each of the processes is not known Apriority.

Q. Consider the following set of Processes, assumed to have arrived at time 0 . Consider the CPU scheduling algorithms Shortest Job First (SJF) and Round Robin (RR). For *RR* assume that the processes are scheduled in the order $P_1, P_2, P_3, P_4$.

| Processes | $P_1$ | $P_2$ | $P_3$ | $P_4$ |
|---|---|---|---|---|
| Burst time (in ms) | 8 | 7 | 2 | 4 |

If the time quantum for $RR$ is 4 ms, then the absolute value of the difference between the average turnaround times (in $ms$ ) of $SJF$ and $RR$ (round off to 2 decimal places) is

Q.

Consider a System using Round Robin Scheduling with 10 Processes all arriving at the time 0. Each Process is associated with 20 identical Request. Each Process request consumes 20 ms of CPU time after which it spends 10 ms of time on I/O, thereafter, initiates subsequent Request. Assuming Scheduling Overhead of 2 ms and Time Quantum of 20 ms, Calculate

i. Response time of the 1st request of the 1st Process

ii. Response time of the 1st request of the last Process

iii. Response time of the subsequent request of any Process.

**Q.** Consider four Processes P, Q, R, and S scheduled on a CPU as per Round Robin Algorithm with a Time Quantum of 4 units. The Processes arrive in the order P, Q, R, S, all at time $t = 0$. There is exactly one context switch from S to Q, exactly one context switch from R to Q, and exactly two context switches from Q to R. There is no context switch from S to P. Switching to a ready process after the termination of another process is also considered a context switch. Which one of the following

(A) $P = 4, Q = 10, R = 6, S = 2$

(B) $P = 2, Q = 9, R = 5, S = 1$

(C) $P = 4, Q = 12, R = 5, S = 4$

(D) $P = 3, Q = 7, R = 7, S = 3$

Q. Consider a System using RR Scheduling with TQ of 'Q' seconds & CPU Scheduling overhead is 'S' seconds. Each Process on an average run for 'T' seconds before blocking on I/O. Give a formula for CPU efficiency for each of the following conditions.

1. $Q = \infty$
2. $Q > T$
3. $S < Q < T$
4. $Q = S$
5. $Q \approx 0$

**Q.** Consider a System using Preemptive Priority based scheduling with dynamically changing priorities. On its arrival a Process is assigned a priority of zero and Running Process Priority increases at the rate of ' $\beta$ ' and Priority of the Processes in the ready $Q$ increases at the rate of ' $\alpha$ '. By dynamically changing the values of $\alpha$ and $\beta$ one can achieve different Scheduling disciplines among the Processes. What discipline will be followed for the following conditions.

1. $\beta > \alpha > 0$
2. $\alpha < \beta < 0$

Q.

Consider Processes $P_1$&$P_2$ arriving in the ready queue at time 0 with following properties.

i) P1 needs a total of 12 units of CPU time and 20 units of I/O time. After every 3 units of $CPU$ time $P1$ spends 5 units on I/O.

ii) $P2$ needs a total of 15 units of $CPU$ time and no I/O. P2 arrives just after P1.

Compute the Completion times of $P_1$&$P_2$ using the following scheduling techniques:

1. SRTF
2. Round Robin with Time Quanta = 4 units

**Q.**

Three processes A, B and C each execute a loop of 100 iterations. In each iteration of the loop, a process performs a single computation that requires tc CPU milliseconds and then initiates a single I/O operation that lasts for $t_{io}$ milliseconds. It is assumed that the computer where the processes execute has sufficient number of I/O devices and the OS of the computer assigns different I/O devices to each process. Also the scheduling overhead of the OS is negligible. The processes have the following characteristics:

| Process Id | $t_c$ | $t_{io}$ |
|---|---|---|
| A | 100 ms | 500 ms |
| B | 350 ms | 500 ms |
| C | 200 ms | 500 ms |

The processes A, B, and C are started at times 0,5 and 10 milliseconds respectively in a pure time-sharing system (round robin scheduling) that uses a time slice of 50 milliseconds. The time in milliseconds at which process C would complete its first I/O operation is


THANK YOU
GW
SOLDIERS !