Embedded systems

Exercise session 5

Task Scheduling

Today

- Simplified programming environment
- Scheduling
- Exercise 1
- Exercise 2
- Exercise 3

Simplified programming environment I

Hypotheses

- Fixed number of tasks
- Each task is characterized by a distinct and constant priority
- Execution requests occur periodically
- Execution times are constant
- Context switches are instantaneous and preemptive

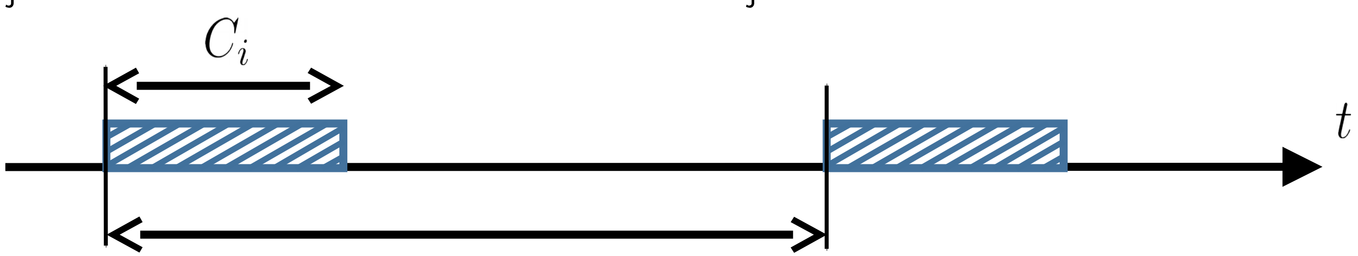
Additionally, the following real-time constraint must be satisfied:

Each execution of a task must finish before or at the same time as the next execution request for this task

Simplified programming environment II

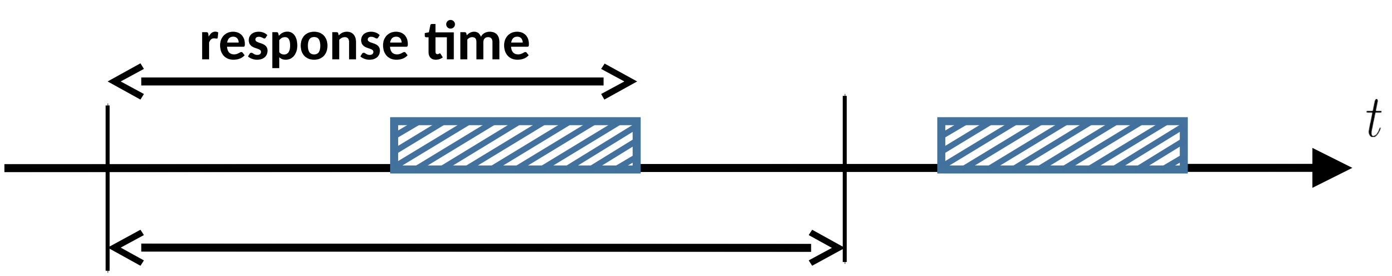
Task

A task τ_j is characterized by a period T_j and an execution time C_j.



Response time

The response time of an execution request for a task τ_j is the delay between this request and the end of the execution of this task.



Simplified programming environment III

Critical instant

A critical instant for a task τ_i is an occurrence of an execution request for that leads to the *largest possible response time* for this task.

Theorem 1: A critical instant for τ_i occurs when an execution request for this task happens at the same time that the execution of all higher priority tasks is requested.

Processor load factor

The processor load factor of a set of tasks with respective periods and execution times and is defined by:

$$U = \sum_{i=1}^{n} \frac{C_i}{T_i}$$

Scheduling I

Schedulable tasks

A set of tasks is schedulable (with respect to a given priority assignment) if the response time of each task is always less than or equal to its period.

Rate-Monotonic Scheduling

Given a set of tasks τ_1 ,τ_2 ,...,τ_n with respective periods T_1 , T_2 ,..., T_n, the Rate-Monotonic Scheduling (RMS) strategy consists in assigning distinct priorities P_1, P_2, ..., P_n to the task, such that for all I,j :

$$T_i < T_j \Rightarrow P_i > P_j$$

Theorem 2: If a set of tasks is schedulable with respect to some priorities assignment, then is it schedulable with the RMS priorities assignment.

Scheduling II

How to know if a set of task is schedulable

The following algorithm is used to check efficiently whether a set of n periodic tasks with a processor load factor U is schedulable or not:

1)If U $>$ 100% $\rightarrow$ Not schedulable

2)If U $<$ 69% $\rightarrow$ Schedulable

3)If U $<$ n($2^{1/n}$-1)% $\rightarrow$ Schedulable

4)Otherwise, perform an exact scheduling simulation based on a RMS priority assignment to find out.

Exercise 1

- Every tasks is represented by (T,C).
- Are the following set of tasks schedulable ?

  1) { (5,1) ; (6,2) ; (7,4) }

  2) { (5,2) ; (16,3) }

  3) { (7,1) ; (8,2) ; (9,3) }

  4) { (2,1) ; (4,1) ; (8,1) ; (16,2) }

  5) { (8,1) ; (6,1) ; (6,1) ; (15,1) ; (5,1) ; (10,2) }

  6) { (5,4) ; (5,1) }

Exercise 1

1. { (5,1) ; (6,2) ; (7,4) }

$$U = \frac{1}{5} + \frac{2}{6} + \frac{4}{7} \approx 110\% \quad \Rightarrow \quad U > 100\%$$

$\rightarrow$ **Not Schedulable**

2. { (5,2) ; (16,3) }

$$U = \frac{2}{5} + \frac{3}{16} = 58.75\% \qquad U < 69\%$$

$\rightarrow$ **Schedulable**

3. { (7,1) ; (8,2) ; (9,3) }

$$U = \frac{1}{7} + \frac{2}{8} + \frac{3}{9} = 72\%$$

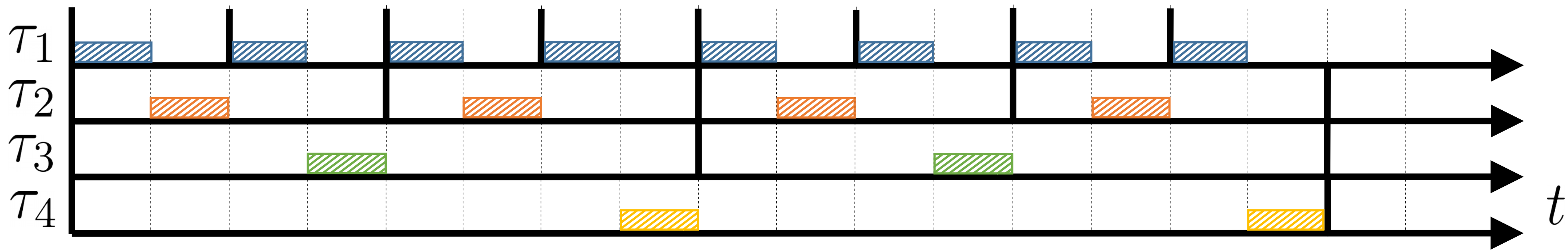
$$U > 69\%$$
$$U < 3(2^{\frac{1}{3}} - 1) \approx 78\%$$

$\rightarrow$ **Schedulable**

Exercise 1

4. { (2,1) ; (4,1) ; (8,1) ; (16,2) }

$$U = \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{2}{16} = 100\% \quad \Rightarrow$$ **RMS priorities assignment**



You have also seen during the course that the sets of tasks such that

$\forall i, j : i < j \Rightarrow T_j$ is an integer multiple of T_i

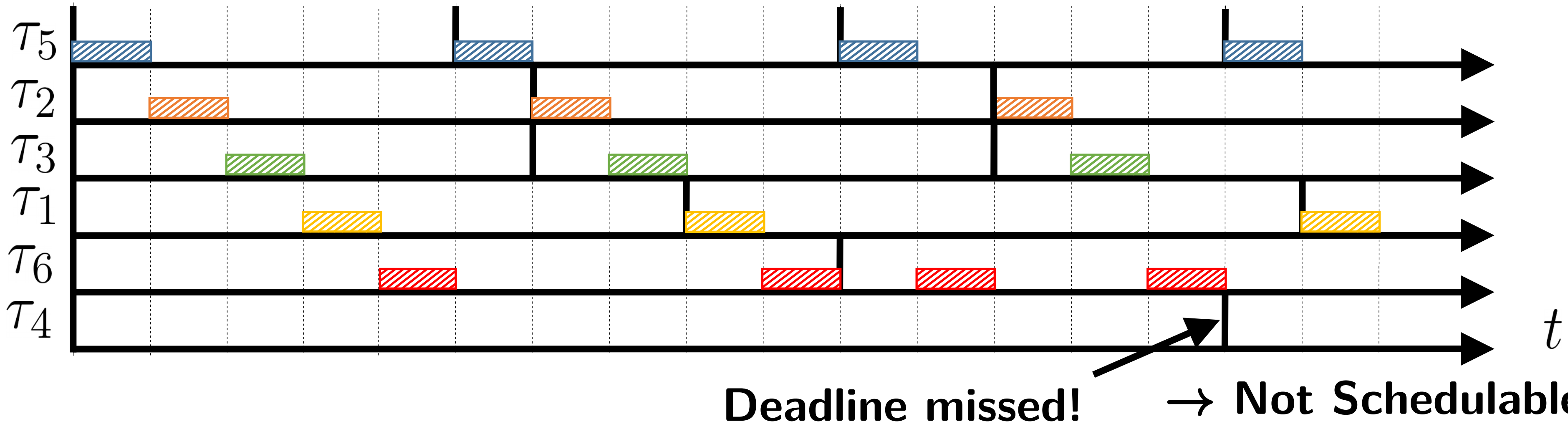
are schedulable if $U \leq 100\%$.

$\rightarrow$ **Schedulable**

Exercise 1

5. { (8,1) ; (6,1) ; (6,1) ; (15,1) ; (5,1) ; (10,2) }

$$U = \frac{1}{8} + 2\frac{1}{6} + \frac{1}{15} + \frac{1}{5} + \frac{2}{10} = 92.5\% \quad \Rightarrow$$ **RMS priorities assignment**



→ **Not Schedulable**

6. { (5,4) ; (5,1) }

$$U = \frac{4}{5} + \frac{1}{5} = 100\%$$

cf. Ex 4. → **Schedulable**

Exercise 2

Two periodic tasks τ_1 and τ_2 are characterized by their respective periods T_1=1ms and T_2=3.5ms. The execution time C2 of τ_2 is equal to 1.2ms. For which value(s) of C_2 does this pair of tasks fully use the processor? (Justify all steps of your reasoning)

(Short answer: C1=0.6ms)

Exercise 3

1. Determine graphically the maximum execution time C, for which the following set of tasks $\{(T_i, C_i)\}$ is schedulable.

$$\{\ (5,1)\ ;\ (10,3)\ ;\ (15,4)\ ;\ (16, C)\ \}$$

2. Determine graphically the maximum execution time C, for which the following set of tasks $\{(T_i, C_i)\}$ is schedulable.

$$\{\ (5,1)\ ;\ (10,3)\ ;\ (15,4)\ ;\ (11, C)\ \}$$

3. Determine graphically the minimum period T, for which the following set of tasks $\{(T_i, C_i)\}$ is schedulable.

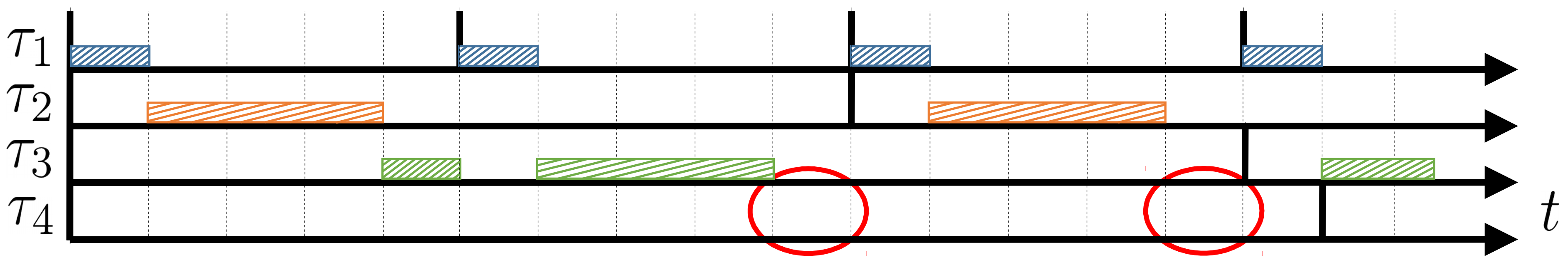
$$\{\ (5,1)\ ;\ (8,2)\ ;\ (10,2)\ ;\ (T,2)\ \}$$

Exercise 3

1. max C such that the following set of tasks is schedulable.

{ (5,1) ; (10,3) ; (15,4) ; (16,C) }

$$U = \frac{1}{5} + \frac{3}{10} + \frac{4}{15} + \frac{C}{16} < 100\% \Rightarrow C < 3.73$$



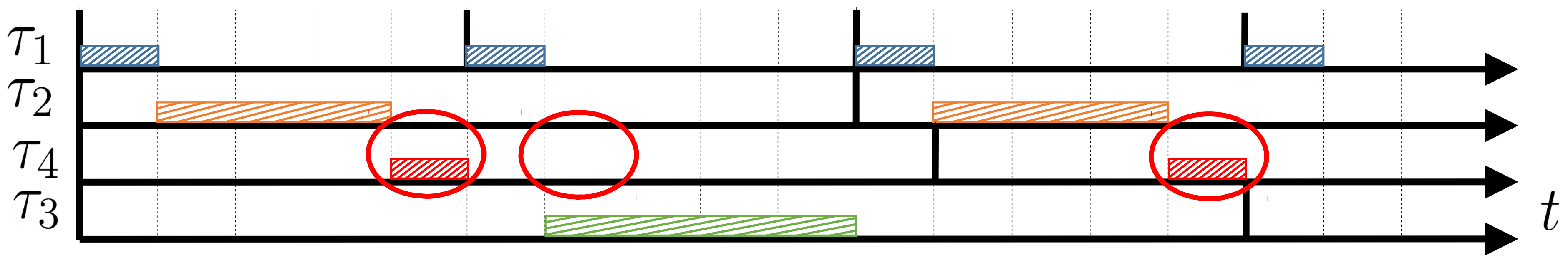
$$\Rightarrow C = 2$$

Exercise 3

2. max C such that the following set of tasks is schedulable.

{ (5,1) ; (10,3) ; (15,4) ; (11,C) }

$$U = \frac{1}{5} + \frac{3}{10} + \frac{4}{15} + \frac{C}{11} < 100\% \Rightarrow C < 2.57$$



$$\Rightarrow C = 1$$

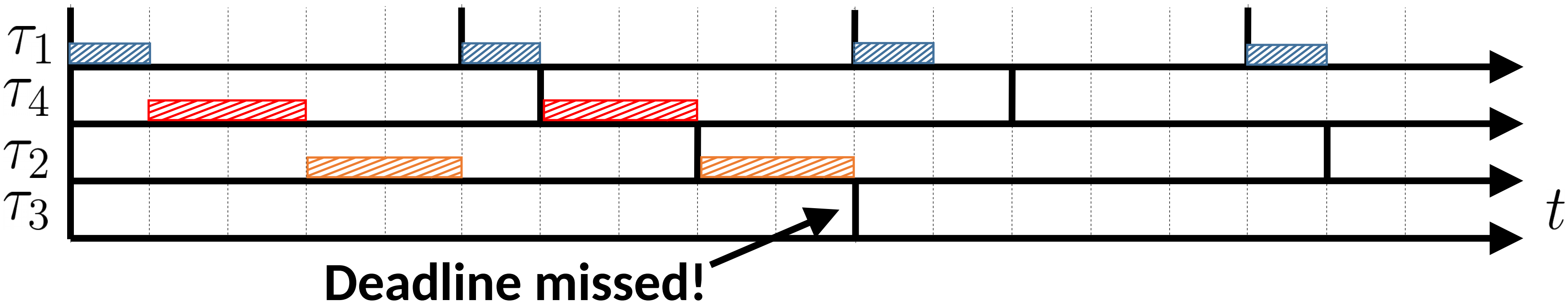
Exercise 3

3. min T such that the following set of tasks is schedulable.

{ (5,1) ; (8,2) ; (10,2) ; (T,2) }

$$U = \frac{1}{5} + \frac{2}{8} + \frac{2}{10} + \frac{2}{T} < 100\% \Rightarrow T > 5.71$$

Let's try with $T = 6$



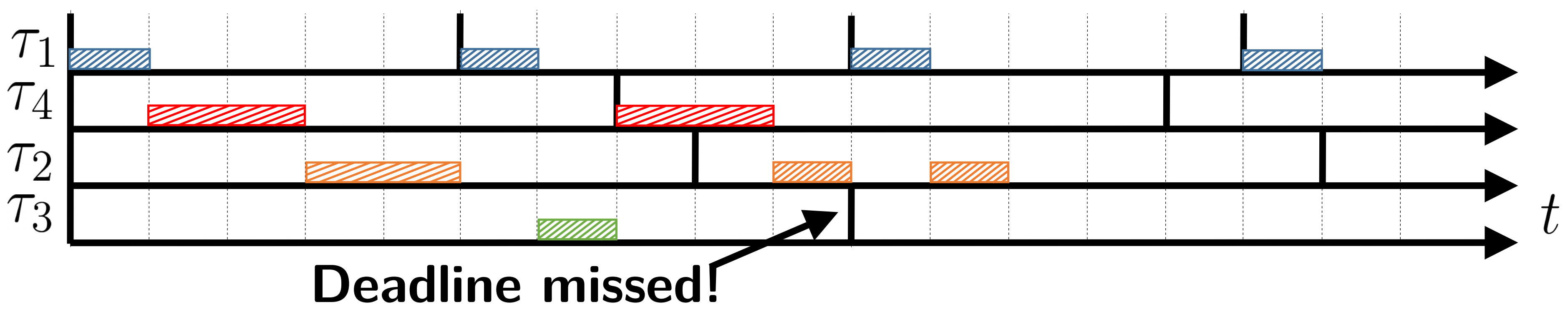
Exercise 3

3. min T such that the following set of tasks is schedulable.

{ (5,1) ; (8,2) ; (10,2) ; (T,2) }

$$U = \frac{1}{5} + \frac{2}{8} + \frac{2}{10} + \frac{2}{T} < 100\% \Rightarrow T > 5.71$$

Let's try with $T = 7$



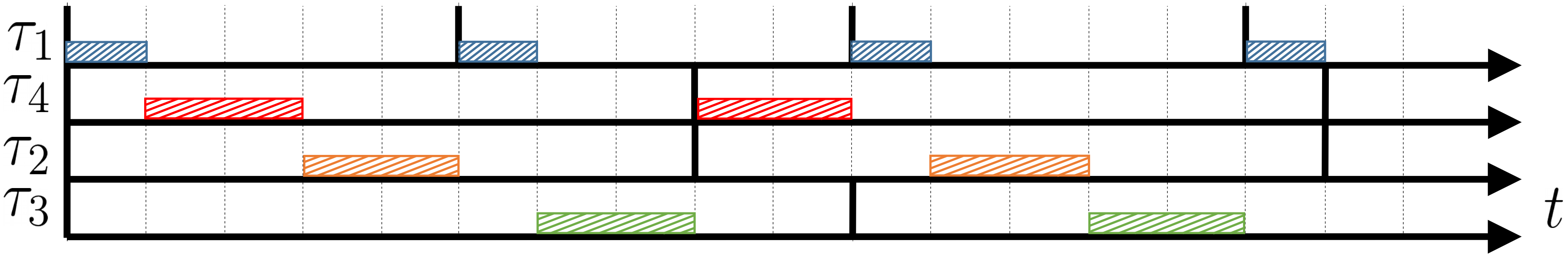
Exercise 3

3. min T such that the following set of tasks is schedulable.

{ (5,1) ; (8,2) ; (10,2) ; (T,2) }

$$U = \frac{1}{5} + \frac{2}{8} + \frac{2}{10} + \frac{2}{T} < 100\% \Rightarrow T > 5.71$$

Let's try with $T = 8$



$$\Rightarrow T = 8$$

Exercise 4

Two Consider the following set of tasks $\tau_i=\{C_i,T_i\}$:

$$\{\ \tau_1=(3,13),\ \tau_2=(1,3),\ \tau_3=(\alpha,5)\ \},$$

where α is a parameter.

(a)Compute the maximum value of α for this set of task to be schedulable (justify all steps of your reasoning).

(b)Verify your answer with a graphical simulation.

(Short answer: C1=5/3=1.666...)