1. Indicate whether the following statements are true or false. Justify your answers.

(a) In the dining-philosopher problem with five philosophers, if we allow at most four of them to be hungry simultaneously, deadlock may still occur.

(b) It is impossible to have a deadlock involving only one single process.

(c) If a resource allocation graph contains a cycle, then a deadlock has occurred.

1a) In the dining-philosopher problem with five philosophers, if we allow at most four of them to be hungry simultaneously, deadlock may still occur.

→ False.

Justification: Deadlock does not occur, since at least one philosopher can get both chopsticks.

1b) It is impossible to have a deadlock involving only one single process.

→ True.

Justification: The hold-and-wait condition can never be satisfied.

1c) If a resource allocation graph contains a cycle, then a deadlock has occurred.

→ False.

Justification: It depends on the number of instances per resource type.

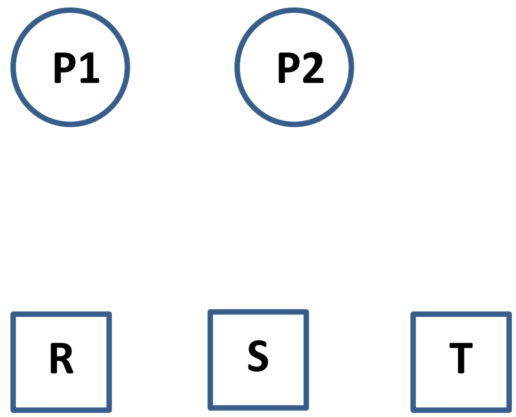
2. Use resource-allocation graphs to model the following situations, and determine if deadlock occurs in each case. There are three resource types, R, S, and T, each having a single instance.

Case 1	Case 2
P1 requests R	P1 requests R
P2 requests T	P2 requests T
P1 requests S	P1 requests S
P2 requests S	P2 requests S
P1 releases R	P1 requests T
P1 releases S	

Case 1: Resource Graph

<u>Case 1</u>

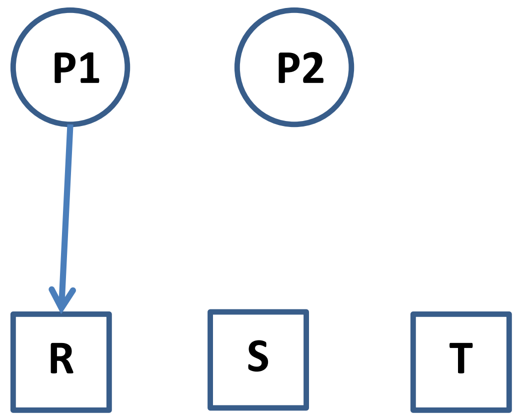
P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

Case 1

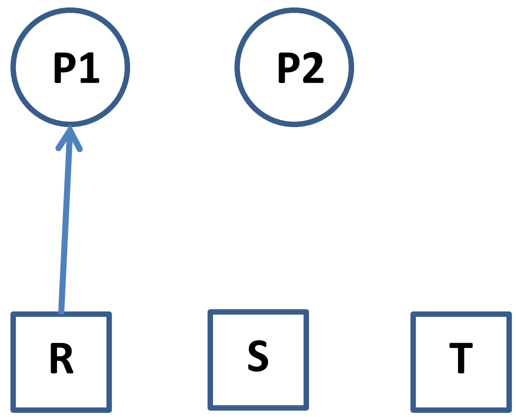
P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

<u>Case 1</u>

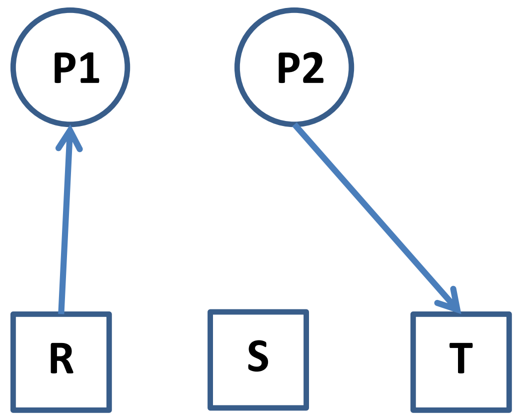
P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

<u>Case 1</u>

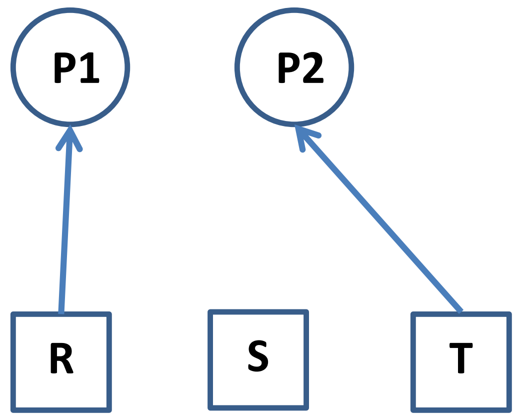
P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

<u>Case 1</u>

P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

Case 1

P1 requests R

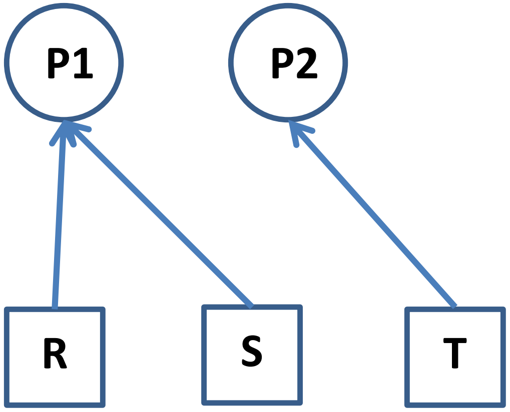
P2 requests T

P1 requests S

P2 requests S

P1 releases R

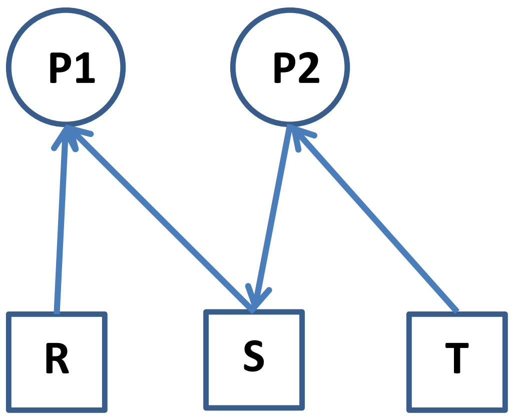
P1 releases S



Case 1: Resource Graph

Case 1

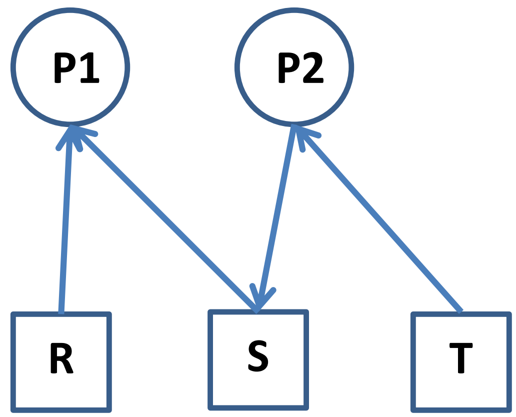
P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

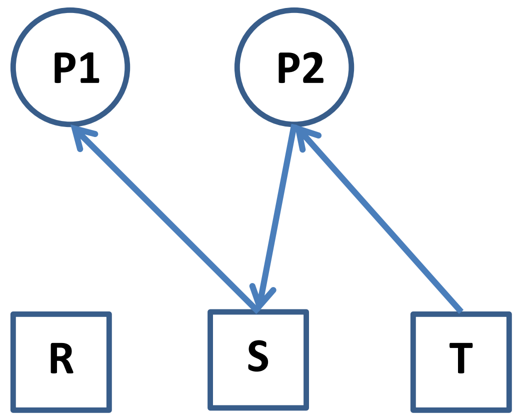
<u>Case 1</u>

P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

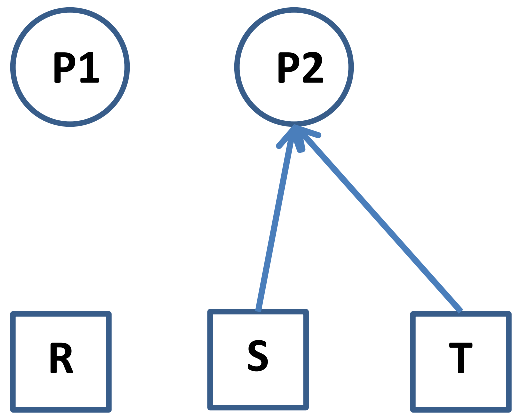
<u>Case 1</u>
P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S



Case 1: Resource Graph

<u>Case 1</u>

P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 releases R
P1 releases S

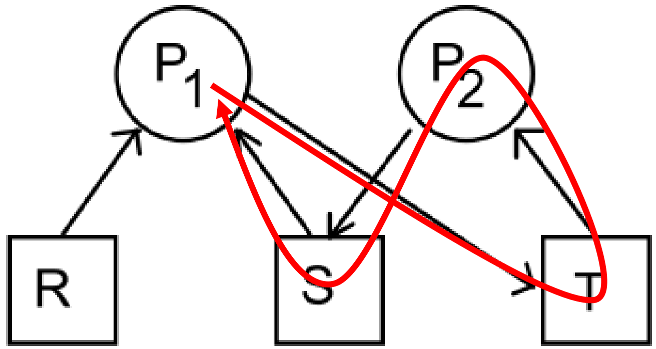


No deadlock.

Case 2: Resource Graph

<u>Case 2</u>

P1 requests R
P2 requests T
P1 requests S
P2 requests S
P1 requests T



Deadlock!

3. A resource-allocation state is given below. Assume Available = 2

	Allocation	Max	Need
PROCESS 1	1	6	5
PROCESS 2	1	5	4
PROCESS 3	2	4	2
PROCESS 4	4	7	3

(a) If PROCESS 4 requests for one more unit of the resource, does this lead to a safe state or an unsafe one?

(b) If PROCESS 3 requests for one more unit of the resource, does this lead to a safe state or an unsafe one?

If PROCESS 4 requests for one more unit…

	Allocation	Max	Need
PROCESS 1	1	6	5
PROCESS 2	1	5	4
PROCESS 3	2	4	2
PROCESS 4	4	7	3

Available = 2

⇓

	Allocation	Max	Need
PROCESS 1	1	6	5
PROCESS 2	1	5	4
PROCESS 3	2	4	2
PROCESS 4	**5**	7	**2**

Available = 1

→unsafe, since $Need_i$ > Available for all *i*.

If PROCESS 3 requests for one more unit…

	Allocation	Max	Need
PROCESS 1	1	6	5
PROCESS 2	1	5	4
PROCESS 3	2	4	2
PROCESS 4	4	7	3

Available = 2

	Allocation	Max	Need
PROCESS 1	1	6	5
PROCESS 2	1	5	4
PROCESS 3	**3**	4	**1**
PROCESS 4	5	7	2

Available = 1

→Safe, since sequence <PROCESS 3, PROCESS 2, PROCESS 1, PROCESS 4> satisfies safety requirement.

4. Consider the following snapshot of a system's state, with four processes (P0, P1, P2 and P3) and three resource types (A, B and C). The current Allocation, Need and Available matrices are shown in the below table. Compute the minimum value for *x*, so that this system state is safe. Justify your answer.

Process	Allocation	Need	Available
	A B C	A B C	A B C
			0 1 x
P0	2 1 1	0 1 0	
P1	1 1 0	2 1 2	
P2	1 1 1	2 0 1	
P3	1 1 1	4 1 0	

The minimum value of x is 0 with the safe sequence <P0,P2,P1,P3>.

Running the safety algorithm, Available matrix evolves as follows.

Available	Need	Allocation	Process completion
	A B C	A B C	
0 1 x=0	0 1 0	2 1 1	P0
2 2 1	2 0 1	1 1 1	P2
3 3 2	2 1 2	1 1 0	P1
4 4 2	4 1 0	1 1 1	P3
5 5 3			