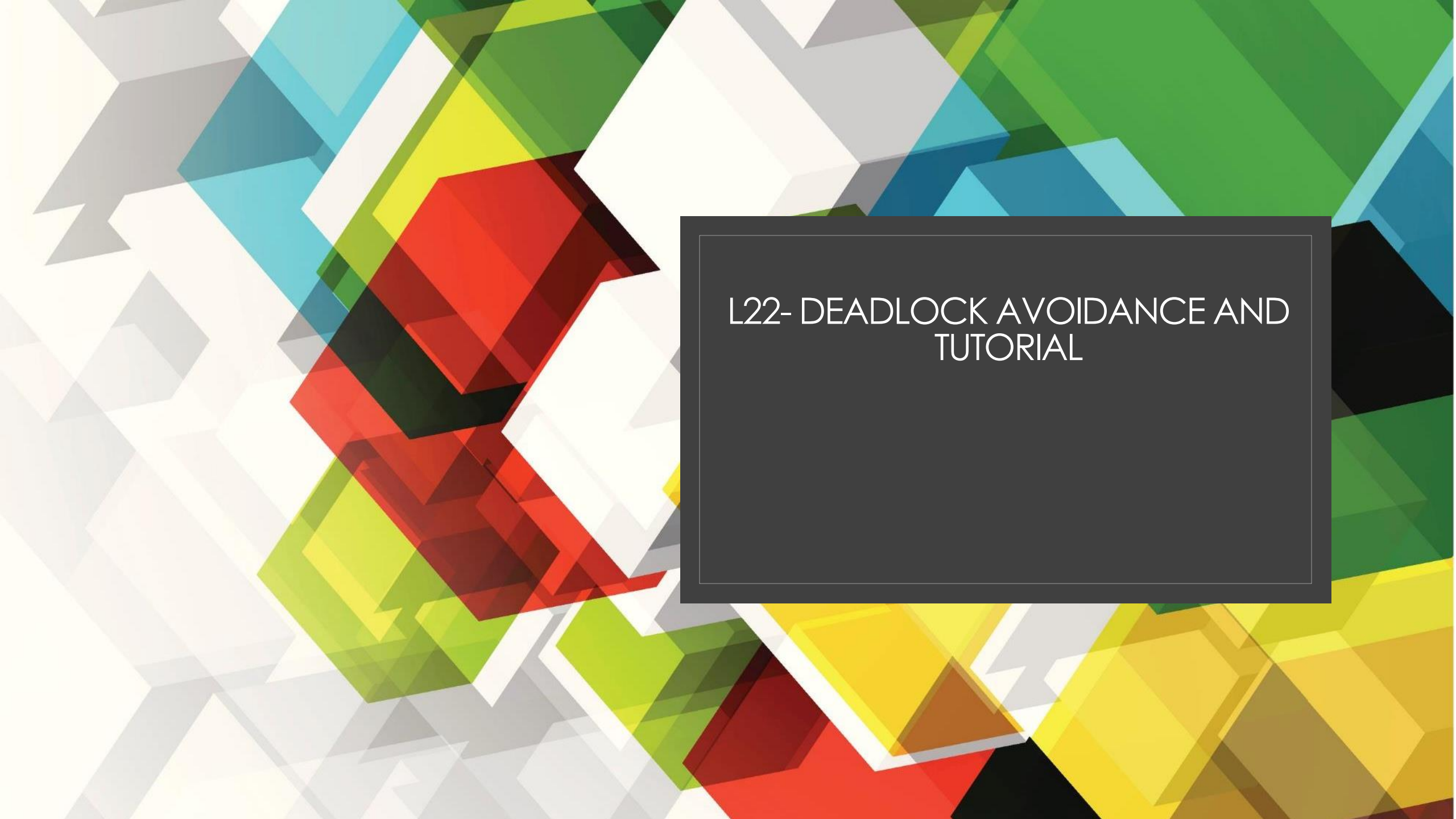

L22- DEADLOCK AVOIDANCE AND TUTORIAL

# Overview of Deadlock Management Section

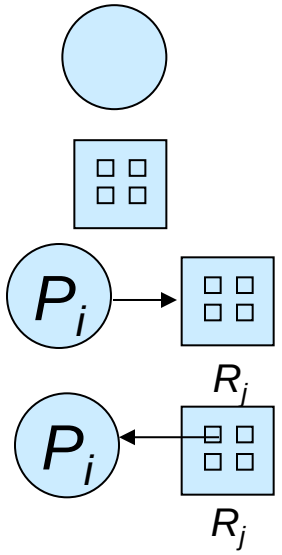
- System Model
- Deadlock Characterization
- Methods for Handling Deadlocks
- Deadlock Prevention
- Deadlock Avoidance

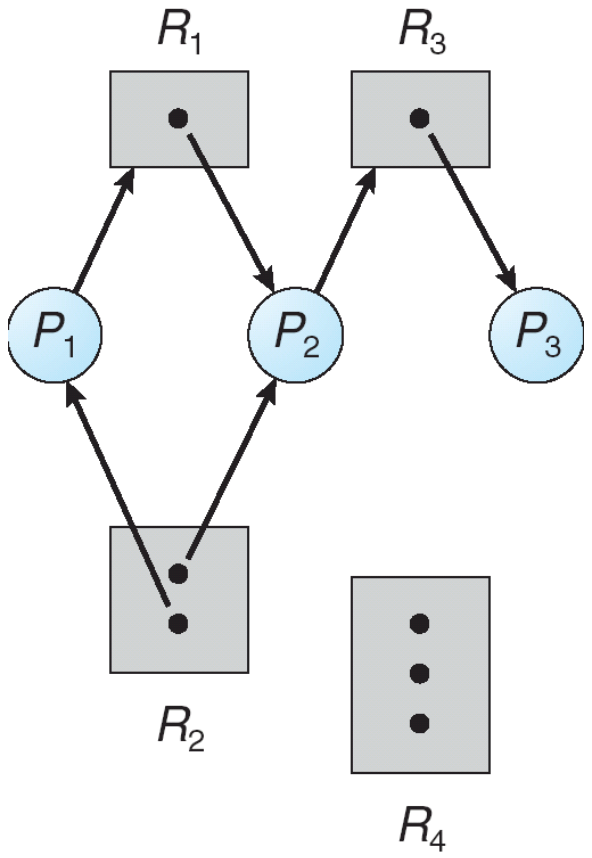
# Deadlock Characterization

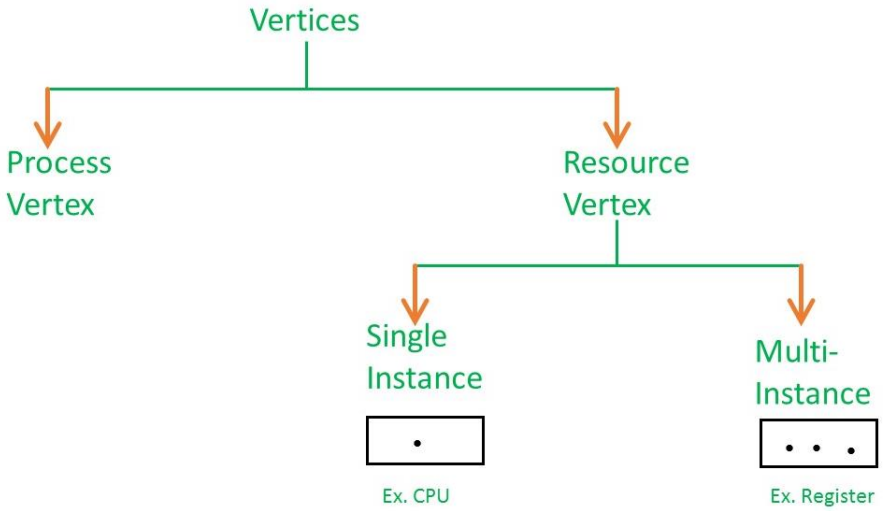
- Deadlock can arise if the following four conditions hold simultaneously.
- **Mutual exclusion**: Only one process at a time can use a resource
- **Hold and wait**: A process holding at least one resource is waiting to acquire additional resources held by other processes
- **No preemption**: A resource can be released only voluntarily by the process holding it, after that process has completed its task
- **Circular wait**: There exists a set $\{P_0, P_1, \ldots, P_n\}$ of waiting processes such that $P_0$ is waiting for a resource that is held by $P_1$, $P_1$ is waiting for a resource that is held by $P_2$, …, $P_{n-1}$ is waiting for a resource that is held by $P_n$, and $P_n$ is waiting for a resource that is held by $P_0$.

# Resource-Allocation Graph

- Process
- Resource Type with 4 instances
- $P_i$ requests an instance of $R_j$
- $P_i$ is holding an instance of $R_j$



# Deadlock Avoidance

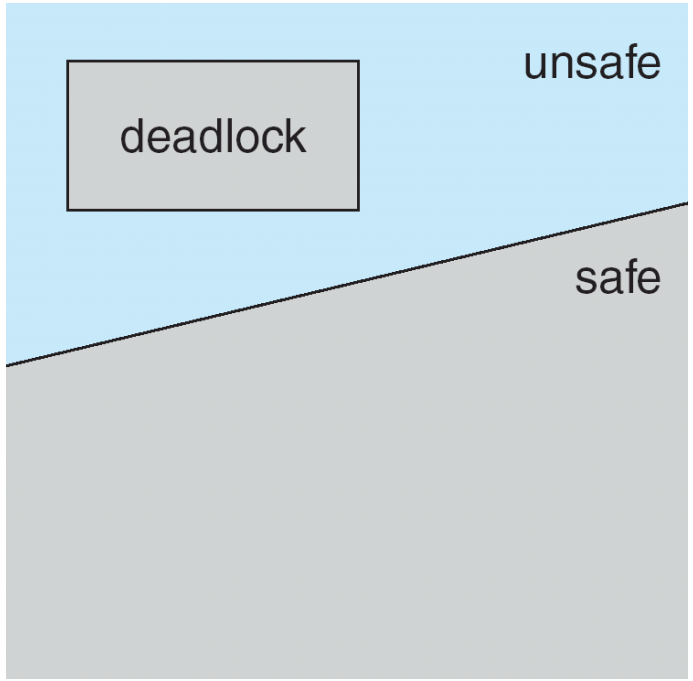
- Requires that the system has some additional ***a priori*** information available
- Simplest and most useful model requires that each process declare the ***maximum number*** of resources of each type that it may need
- The deadlock-avoidance algorithm dynamically examines the resource-allocation state to ensure that there can never be a circular-wait condition
- Resource-allocation *state* is defined by the number of available and allocated resources, and the maximum demands of the processes

# Safe State

- When a process requests an available resource, system must decide if immediate allocation leaves the system in a safe state
- System is in **safe state** if there exists a sequence $<P_1, P_2, \ldots, P_n>$ of ALL the processes in the systems such that for each $P_i$, the resources that $P_i$ can still request can be satisfied by currently available resources + resources held by all the $P_j$, with $j < i$
- That is:
  - If $P_i$ resource needs are not immediately available, then $P_i$ can wait until all $P_j$ have finished
  - When $P_j$ is finished, $P_i$ can obtain needed resources, execute, return allocated resources, and terminate
  - When $P_i$ terminates, $P_{i+1}$ can obtain its needed resources, and so on

# Safe State & Deadlock

- If a system is in safe state ⇒ no deadlocks
- If a system is in unsafe state ⇒ possibility of deadlock
- Avoidance ⇒ ensure that a system will never enter an unsafe state.



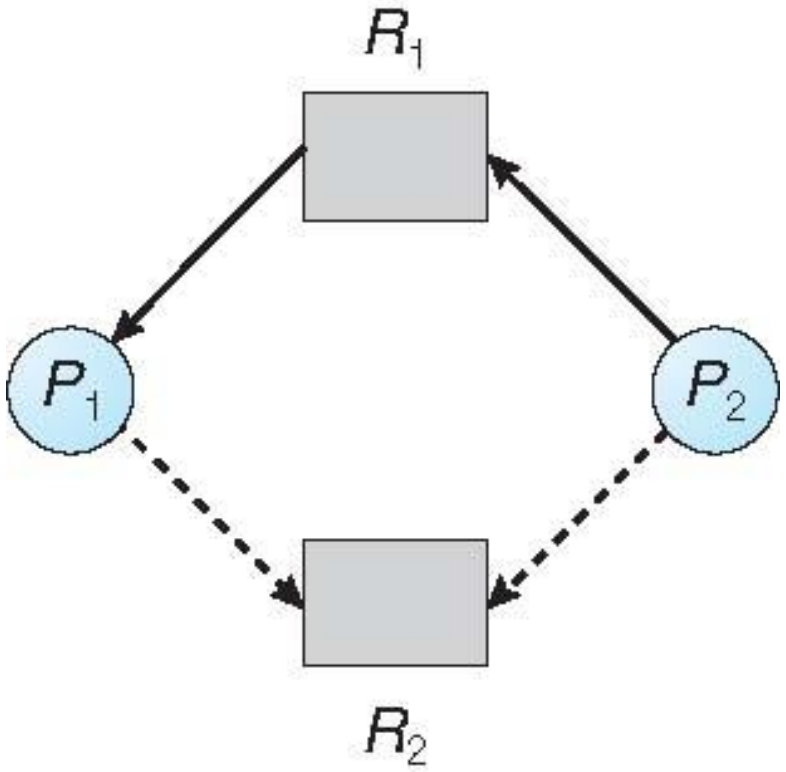
# Avoidance Algorithms

- Single instance of a resource type
  - Use a resource-allocation graph
- Multiple instances of a resource type
  - Use the banker’s algorithm

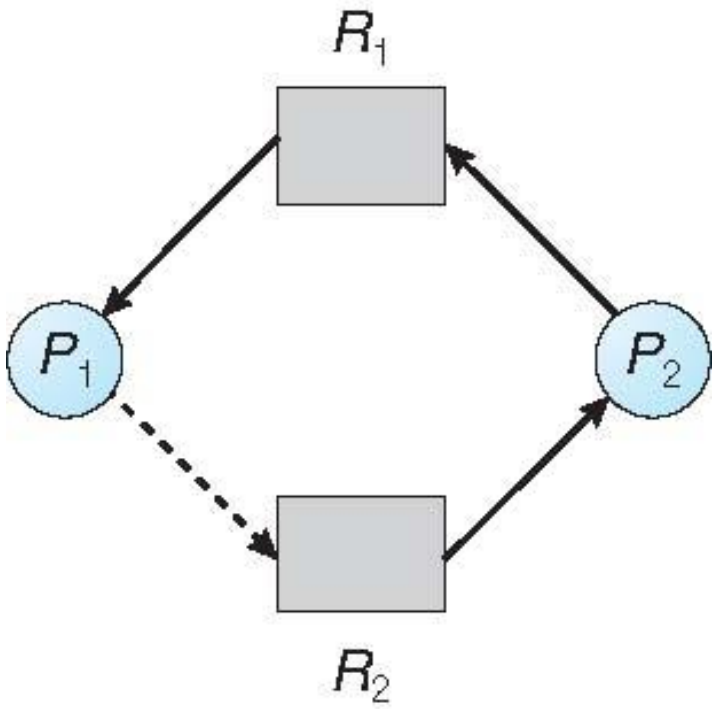
# Resource-Allocation Graph Scheme

- **Claim edge** $P_i \rightarrow R_j$ indicated that process $P_i$ may request resource $R_j$
- Claim edge is represented by a dashed line
- Claim edge converts to request edge when a process requests a resource
- Request edge converted to an assignment edge when the resource is allocated to the process
- When a resource is released by a process, assignment edge reconverts to a claim edge
- Resources must be claimed *a priori* in the system

# Resource-Allocation Graph & Unsafe State




Resource-Allocation Graph
with Claim Edges




Unsafe State In
Resource-Allocation Graph

# Resource-Allocation Graph Algorithm

- Suppose that process $P_i$ requests a resource $R_j$
- The request can be granted only if converting the request edge to an assignment edge does not result in the formation of a cycle in the resource allocation graph

# Banker's Algorithm

- Multiple instances
- Each process must a priori claim maximum use
- When a process requests a resource it may have to wait
- When a process gets all its resources it must return them in a finite amount of time

# Data Structures for the Banker's Algorithm

- Let n = number of processes, and m = number of resources type
- **Available**: Vector of length m. If available [j] = k, there are k instances of resource type $R_j$ available
- **Max**: n x m matrix. If Max [i,j] = k, then process $P_i$ may request at most k instances of resource type $R_j$
- **Allocation**: n x m matrix. If Allocation[i,j] = k then $P_i$ is currently allocated k instances of $R_j$
- **Need**: n x m matrix. If Need[i,j] = k, then $P_i$ may need k more instances of $R_j$ to complete its task
  - Need [i,j] = Max[i,j] – Allocation [i,j]

# Safety Algorithm

1. Let **Work** and **Finish** be vectors of length m and n, respectively.

   Initialize: **Work = Available**

   **Finish [i] = false for i = 0, 1, …, n- 1**

2. Find an **i** such that both:

   (a) **Finish [i] = false**

   (b) $\mathbf{Need_i} \leq \mathbf{Work}$

   If no such **i** exists, go to step 4

3. **Work = Work + Allocation$_i$**
   **Finish[i] = true**
   go to step 2

4. If **Finish [i] == true** for all **i**, then the system is in a safe state

# Resource-Request Algorithm for Process $P_i$

- **$Request_i$** = request vector for process **$P_i$**.
- If **$Request_i[j] = k$** then process **$P_i$** wants **k** instances of resource type **$R_j$**

1. If **$Request_i \leq Need_i$** go to step 2. Otherwise, raise error condition, since process has exceeded its maximum claim
2. If **$Request_i \leq Available$**, go to step 3. Otherwise **$P_i$** must wait, since resources are not available
3. Pretend to allocate requested resources to **$P_i$** by modifying the states

$$Available = Available - Request_i;$$
$$Allocation_i = Allocation_i + Request_i;$$
$$Need_i = Need_i - Request_i;$$

- If safe $\Rightarrow$ the resources are allocated to **$P_i$**
- If unsafe $\Rightarrow$ **$P_i$** must wait, and the old resource-allocation state is restored

# Example of Banker's Algorithm

- 5 [ $P_0$ -$P_4$] & 3 resource types: A (10), B (5), and C (7)
- Snapshot at time $T_0$:

| | Allocation | Max | Available |
|---|---|---|---|
| | A B C | A B C | A B C |
| $P_0$ | 0 1 0 | 7 5 3 | 3 3 2 |
| $P_1$ | 2 0 0 | 3 2 2 | |
| $P_2$ | 3 0 2 | 9 0 2 | |
| $P_3$ | 2 1 1 | 2 2 2 | |
| $P_4$ | 0 0 2 | 4 3 3 | |

# Example of Banker's Algorithm contd...

- The content of the matrix **Need** is defined to be **Max – Allocation**

| | Need |
|---|---|
| | A B C |
| $P_0$ | 7 4 3 |
| $P_1$ | 1 2 2 |
| $P_2$ | 6 0 0 |
| $P_3$ | 0 1 1 |
| $P_4$ | 4 3 1 |

The system is in a safe state since the sequence $< P_1, P_3, P_4, P_2, P_0 >$ satisfies safety criteria

# Example: $P_1$ Request (1,0,2)

- Check that Request ≤ Available (that is, (1,0,2) ≤ (3,3,2) ⇒ true

| | Allocation | Need | Available |
|---|---|---|---|
| | A B C | A B C | A B C |
| $P_0$ | 0 1 0 | 7 4 3 | 2 3 0 |
| $P_1$ | 3 0 2 | 0 2 0 | |
| $P_2$ | 3 0 2 | 6 0 0 | |
| $P_3$ | 2 1 1 | 0 1 1 | |
| $P_4$ | 0 0 2 | 4 3 1 | |

- Executing safety algorithm shows that sequence < **$P_1$, $P_3$, $P_4$, $P_0$, $P_2$**> satisfies safety requirement

# Semaphore Synchronization

Q1: Consider two processes P and Q with an event Pe and Qe, respectively executing inside a loop. P and Q are executing in a multiprogramming environment on a single processor where context switching can happen arbitrarily at any time. We want events Pe and Qe to strictly execute alternatively in the sequence Pe, Qe, Pe, Qe .. (10 times). Give an algorithmic solution to ensure this using semaphores.

**Process P:**

```
for (i=10; i>0; i--)
{
 WAIT (X)
 Pe
  SIGNAL (Y)
}
```

**Process Q:**

```
for (j=10; i>0; j--)
 {
    WAIT(Y)
   Qe
    SIGNAL (X)
 }
```

# Safe state and Safe sequence

Q2: Consider a system with 4 processes P1, P2, P3 & P4 and 3 resource types R1, R2 & R3. The current Allocation matrix and Need matrix are given below. If there is exactly one instance of all resource types available now, is the system in safe state now? If so, give a safe sequence.

| | Allocation | | | Need | | |
|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R1 | R2 | R3 |
| **P1** | 1 | 0 | 2 | 1 | 2 | 1 |
| **P2** | 1 | 2 | 1 | 2 | 3 | 1 |
| **P3** | 0 | 1 | 1 | 1 | 0 | 1 |
| **P4** | 0 | 1 | 0 | 2 | 2 | 0 |

# Safe state and Safe sequence

| | Allocation | | | Need | | |
|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R1 | R2 | R3 |
| **P1** | 1 | 0 | 2 | 1 | 2 | 1 |
| **P2** | 1 | 2 | 1 | 2 | 3 | 1 |
| **P3** | 0 | 1 | 1 | 1 | 0 | 1 |
| **P4** | 0 | 1 | 0 | 2 | 2 | 0 |

1. Let **Work** and **Finish** be vectors of length m and n, respectively.

   Initialize: **Work = Available**

   **Finish [i] = false for i = 0, 1, …, n- 1**
2. Find an **i** such that both:

   (a) **Finish [i] = false**

   (b) **$Need_i \leq Work$**

   If no such **i** exists, go to step 4
3. **Work = Work + $Allocation_i$**
   **Finish[i] = true**
   go to step 2
4. If **Finish [i] == true** for all **i**, then the system is in a safe state

# Safe state and Safe sequence

Q3: Consider a system with 4 processes P1, P2, P3 & P4 and 3 resource types R1, R2 & R3. The current Allocation matrix and Need matrix are given below. If there is exactly one instance of all resource types available now, is the system in safe state now? If so, give a safe sequence.

| | Allocation | | | Need | | |
|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R1 | R2 | R3 |
| **P1** | 1 | 0 | 2 | 1 | 2 | 1 |
| **P2** | 1 | 2 | 1 | 2 | 3 | 1 |
| **P3** | 0 | 1 | 1 | 1 | 0 | 1 |
| **P4** | 1 | 0 | 1 | 2 | 2 | 0 |

# Safe state and Safe sequence

| | Allocation | | | Need | | |
|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R1 | R2 | R3 |
| **P1** | 1 | 0 | 2 | 1 | 2 | 1 |
| **P2** | 1 | 2 | 1 | 2 | 3 | 1 |
| **P3** | 0 | 1 | 1 | 1 | 0 | 1 |
| **P4** | 1 | 0 | 1 | 2 | 2 | 0 |

1. Let **Work** and **Finish** be vectors of length m and n, respectively.

   Initialize: **Work = Available**

   **Finish [i] = false for i = 0, 1, …, n- 1**
2. Find an **i** such that both:

   (a) **Finish [i] = false**

   (b) **$Need_i \leq Work$**

   If no such **i** exists, go to step 4
3. **Work = Work + $Allocation_i$**
   **Finish[i] = true**
   go to step 2
4. If **Finish [i] == true** for all **i**, then the system is in a safe state

# Critical Section and Semaphores

Q4. Each of a set of *n* processes executes the following code using two semaphores ***a*** and ***b*** initialized to 1 and 0, respectively. Assume that count is a shared variable, initialized to 0 and not used in CODE SECTION P. What does the code achieve?

**CODE SECTION P**

```
wait(a); count=count+1;
if (count==n) signal(b);
signal(a); wait(b); signal(b);
```

**CODE SECTION Q**

(a) It ensures that at most n-1 process are in CODE SECTION Q at any time.

(b) It ensures that all process executes CODE SECTION Q mutually exclusively.

(c) It ensures that at most n-1 process are in CODE SECTION P at any time.

(d)It ensures that no process executes CODE SECTION Q before every process has finished CODE SECTION P

# Thank You