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LAB REPORT

on

OPERATING SYSTEMS

Submitted by

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in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

in

COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING

(Autonomous Institution under VTU)

BENGALURU-560019

Feb-2025 to June-2025

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CERTIFICATE

This is to certify that the Lab work entitled "OPERATING SYSTEMS – 23CS4PCOPS" carried out by Vishwajit Anand (1WA23CS046), who is Bonafide student of B. M. S. College of Engineering. It is in partial fulfilment for the award of Bachelor of Engineering in Computer Science and Engineering of the Visvesvaraya Technological University, Belgaum during the year Feb 2025- June 2025. The Lab report has been approved as it satisfies the academic requirements in respect of a OPERATING SYSTEMS - (23CS4PCOPS) work prescribed for the said degree.

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Course Outcomes

C01	Apply the different concepts and functionalities of Operating System
C02	Analyse various Operating system strategies and techniques
C03	Demonstrate the different functionalities of Operating System.
C04	Conduct practical experiments to implement the functionalities of Operating system.

Program -1

Question:

Write a C program to simulate the following non-pre-emptive CPU scheduling algorithm to find turnaround time and waiting time.

→FCFS

→ SJF (pre-emptive & Non-preemptive)

Code:

```
#include <stdio.h>
void main() {
    int n;
    printf("Enter number of processes: ");
    scanf("%d", &n);
    int arrival[n], burst[n], waiting[n], turnaround[n],
completion[n], response[n];
    printf("Enter Arrival Time and Burst Time for each process:\n");
    for (int i = 0; i < n; i++) {
        printf("Process %d: ", i + 1);
        scanf("%d %d", &arrival[i], &burst[i]);
    }
    int currentTime = 0;
    float totalWaiting = 0, totalTurnaround = 0;

printf("\nProcess\tArrival\tBurst\tWaiting\tTurnaround\tResponse\n");
    for (int i = 0; i < n; i++) {
         if (currentTime < arrival[i])
            currentTime = arrival[i];
        completion[i] = currentTime + burst[i];
        turnaround[i] = completion[i] - arrival[i];
        waiting[i] = turnaround[i] - burst[i];
        response[i] = completion[i] - arrival[i];
        totalWaiting += waiting[i];
        totalTurnaround += turnaround[i];
        printf("%d\t%d\t%d\t%d\t%d\t\t%d\n", i + 1, arrival[i],
burst[i], waiting[i], turnaround[i], response[i]);
        currentTime = completion[i];
    }
    printf("\nAverage Waiting Time: %.2f", totalWaiting / n);
    printf("\nAverage Turnaround Time: %.2f\n", totalTurnaround / n);
}
```

Result:

```
TERMINAL
PS C:\Users\Admin\Documents\temp> cd "c:\Users\Admin\Documents\temp\" ; if ($?) { gcc fcfs.c -o fcfs } ; if ($?) { .\fcfs }
Enter number of processes: 4
Enter Arrival Time and Burst Time for each process:
Process 1: 0
7
Process 2: 0
3
Process 3: 0
4
Process 4: 0
6

Process Arrival Burst   Waiting Turnaround      Response
1       0       7       0       7               7
2       0       3       7       10              10
3       0       4       10      14              14
4       0       6       14      20              20

Average Waiting Time: 7.75
Average Turnaround Time: 12.75
```

=>SJF(Non-preemptive):

Code:

```
#include <stdio.h>
void nonPreemptiveSJF(int n, int at[], int bt[], int ct[], int tat[],
int wt[], int rt[])
{
    int completed = 0, time = 0, min_bt, shortest, finish_time;
    int remaining_bt[n];
    for (int i = 0; i < n; i++)
    {
        remaining_bt[i] = bt[i];
    }

    while (completed < n)
    {
        min_bt = 9999;
        shortest = -1;
        for (int i = 0; i < n; i++)
```

```
        {
            if (at[i] <= time && remaining_bt[i] > 0 && bt[i] <
min_bt)
            {
                min_bt = bt[i];
                shortest = i;
            }
        }
        if (shortest == -1)
        {
            time++;
            continue;
        }
        time += bt[shortest];
        remaining_bt[shortest] = 0;
        completed++;
        ct[shortest] = time;
        tat[shortest] = ct[shortest] - at[shortest];
        wt[shortest] = tat[shortest] - bt[shortest];
        rt[shortest] = wt[shortest];
    }
}

void displayTable(int n, int at[], int bt[], int ct[], int tat[], int
wt[], int rt[])
{
    printf("\nProcess\tAT\tBT\tCT\tTAT\tWT\tRT\n");
    for (int i = 0; i < n; i++)
    {
        printf("%d\t%d\t%d\t%d\t%d\t%d\t%d\n", i + 1, at[i], bt[i],
ct[i], tat[i], wt[i], rt[i]);
    }
}
```

```c
int main()
{
    int n;
    printf("Enter number of processes: ");
    scanf("%d", &n);
    int at[n], bt[n], ct[n], tat[n], wt[n], rt[n];
    printf("Enter Arrival Time and Burst Time for each process:\n");
    for (int i = 0; i < n; i++)
    {
        printf("Process %d - Arrival Time: ", i + 1);
        scanf("%d", &at[i]);
        printf("Process %d - Burst Time: ", i + 1);
        scanf("%d", &bt[i]);
    }
    nonPreemptiveSJF(n, at, bt, ct, tat, wt, rt);
    displayTable(n, at, bt, ct, tat, wt, rt);
    return 0;
}
```

Output:

```
Enter number of processes: 4
Enter Arrival Time and Burst Time for each process:
Process 1 - Arrival Time: 0
Process 1 - Burst Time: 7
Process 2 - Arrival Time: 8
Process 2 - Burst Time: 3
Process 3 - Arrival Time: 3
Process 3 - Burst Time: 4
Process 4 - Arrival Time: 5
Process 4 - Burst Time: 6

Process AT      BT      CT      TAT     WT      RT
1       0       7       7       7       0       0
2       8       3       14      6       3       3
3       3       4       11      8       4       4
4       5       6       20      15      9       9
```

1) First Come First serve -

```
# include <stdio.h>
# include <conio.h>
# include <math.h>

struct process {
        int  process_no;
        int  arrival_time;
        int  response_time;
        int  burst_time;
        int  completion_time;
        int  waiting_time;
        int  turn_around_time;
        };
void  print1( struct process a1[], int n);
void  sort ( struct process a1[],
               int n){

    for(int i=0; i<n-1; i++) {
       for(int j=0; j<n-i-1; j++){
           if ((a1[i].arrival_time)>
                  (a1[j]. arrival_time)) {

                  struct process temp =a1[i]
                  a1[i]= a1[j];
                  a1[j]= temp;
           }
       }
    }
};
```

Date: / /

```
void fcfs (struct process a1[], int n){
    int current_time =0;
    for ( int i=0; i<n; i++) {

        current_time = fmax ( current_time,
                  a1[i]. arrival_time );
        a1[i]. response_time = current_time -
                  a1[i]. arrival_time;
        current_time += a1[i]. burst_time;
        a1[i]. completion_time =
                  current_time;
        a1[i]. turn_around_time =
              a1[i]. completion_time -
              a1[i]. arrival_time;
        a1[i]. waiting_time = a1[i].
              turn_around_time -
              a1[i]. arrival_time;
    }
}

void scan1 ( struct process a1[],
             int n){
    for (int i=0; i<n; i++){
        printf(" Enter process no,
             arrival time, burst time")
        scanf (" %d", & a1[i]. process
                 no);
        scanf (" %d", & a1[i]. arrival_
                 time);
        scanf (" %d", & a1[i]. burst_time);
    }
}
```

```
int main () {
    int n = 4;
    struct process proc[n];
    scan1 ( proc, n);
    sort ( proc, n);
    fcfs ( proc, n);
    print1 ( proc, n);
}

void print1 (struct process a1[]; int n) {
    printf ("\n PID \t AT \t BT \t RT \t CT \t WT \t TAT
    for (int i=0; i<n; i++) {
        printf ("\n %d \t %d \t %d \t %d
                  \t %d \t %d \t %d",
                 a1[i]. process_id , a1[i]. arrival_
                 time, a1[i]. burst_time,
                 a1[i]. response_time,
                 a1[i]. completion_time,
                 a1[i]. waiting_time,
                 a1[i]. turn_around_time);
    }
}
```

=> SJF (Preemptive):

METRO
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```
if (min_index == -1) {
        current_t ++;
    }
else {
    ps[min_index].start_t = current_time;
    ps[min_index].ct = ps[min_index].
          start_t + ps[min_index].bt;
    ps[min_index].tat = ps[min_index].
          ct - ps[min_index].at;
    totalTAT += ps[min_index].tat;
    ps[min_index].wt = ps[min_index].
          tat - ps[min_index].bt
    totalWT += ps[min_index].wt;
    visited[min_index] = true;
    completed ++;
    current_t = ps[min_index].ct;
    }
  }
  printf("The average TAT is: %.2f ms",
        totalTAT /n);

  printf("The average WT is:%.2f ms",
        totalWT /n);

}
```

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```
if (min_index == -1) {
        current_t ++;
    }
else {
    ps[min_index].start_t = current_time;
    ps[min_index].ct = ps[min_index].
            start_t + ps[min_index].bt;
    ps[min_index].tat = ps[min_index].
            ct - ps[min_index].at;
    total TAT += ps[min_index].tat;
    ps[min_index].wt = ps[min_index].
            tat - ps[min_index].bt
    total WT += ps[min_index].wt;
    visited[min_index] = true;
    completed ++;
    current_t = ps[min_index].ct;
    }
}
printf(" The average TAT is : %.2f ms",
        total TAT / n);

printf(" The average WT is: %.2f ms",
        total WT / n);

}
```

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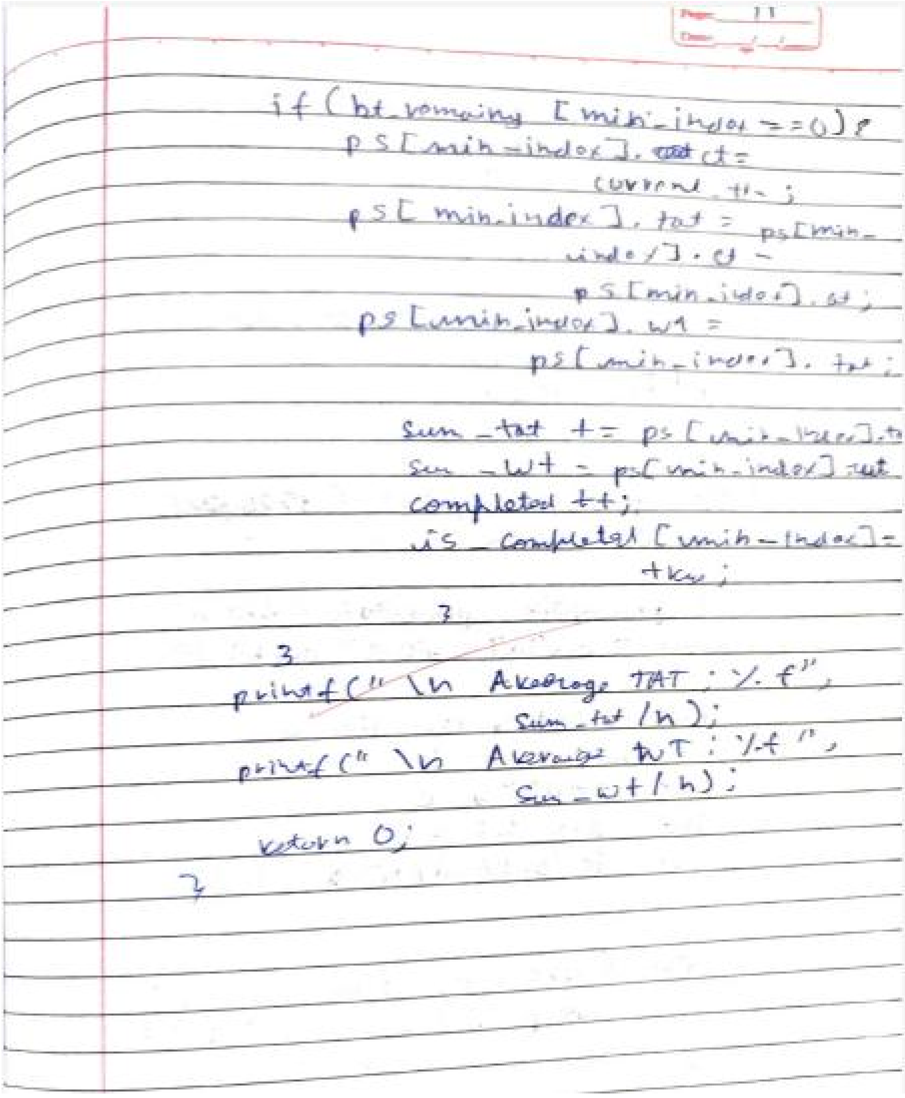
```
if (min_index == -1) {
        current_t ++;
    }
else {
    ps[min_index].start_t = current_time;
    ps[min_index].ct = ps[min_index].
            start_t + ps[min_index].bt;
    ps[min_index].tat = ps[min_index].
            ct - ps[min_index].at;
    total TAT += ps[min_index].tat;
    ps[min_index].wt = ps[min_index].
            tat - ps[min_index].bt
    total WT += ps[min_index].wt;
    visited[min_index] = true;
    completed ++;
    current_t = ps[min_index].ct;
    }
  }
printf("The average TAT is: %.2f ms",
        ~~toto~~ total TAT /n);

printf("The average WT is:%.2f ms",
        total WT /n);

}
```

3) Shortest Job First (preemptive)

```
#include <stdio.h>
#include <stdbool.h>

struct process_s {
  int pid;
  int at, bt, ct, wt, tat, start_time;
  }ps[100];

int main(){
  int n;
  float bt remaining[100];
  bool is_completed [100] = {false};
  int current_time =0, completed = 0;
  float  sum_tat =0, sum_wt =0;

  printf("Enter no. of processes");
  scanf ("%d", &n);
  for (int i =0; i< n; i++){
      printf("
  printf(" Enter arrival times");
  for (int i=0; i <n ; i++){
      scanf ("%d", & ps[i].at);
      ps[i].pid = i;
  }
```

```
printf("Enter Burst Time");
for (int i=0; i<n ; i++){
    scanf ("%d", & ps[i].bt );
    bt remaining [i] = ps[i].bt;
}
while (completed != n){
    int min_index = 1 ;
    int min = 99999 ;
    for (int i=0; i<n ; i ++){
        if( ps[i].at <=
            current_tim &&
            ! is_completed [i] &&
            bt_remaining < min ){
          {min = bt_remaing [i]
           min_index = i;
          }
    }
    if (min_index == -1){
        current_tim ++; }
    else {
      if(bt_remaing [min_index]==
          ps [min_index ].bt ]{

          ps [min_index].start_tm
              = current_tim;
      }
      bt_remaing[min_index ]--;
      current_tim ++;
      prev= current_tim;
```



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```
if (bt_remaining [min_index == 0) {
    ps[min_index].ct =
            current_time;
    ps[min_index].tat = ps[min_index.
            index].ct -
            ps[min_index].at;
    ps[min_index].wt =
            ps[min_index].tat;

        sum_tat += ps[min_index].tat
        sum_wt = ps[min_index].tat
        completed ++;
        is_completed [min_index] =
                true;
    }
}
printf("\n Average TAT : %f",
        sum_tat/n);
printf("\n Average WT : %f",
        sum_wt/n);
return 0;
}
```

Code

```
#include <stdio.h>
void preemptiveSJF(int n, int at[], int bt[], int ct[], int tat[], int wt[], int rt[])
{
    int remaining_bt[n];
    int completed = 0, time = 0, min_bt, shortest;
    int flag[n];
    for (int i = 0; i < n; i++)
```

```
    {
        remaining_bt[i] = bt[i];
        flag[i] = 0;
    }

    while (completed < n)
    {
        min_bt = 9999;
        shortest = -1;
        for (int i = 0; i < n; i++)
        {
            if (at[i] <= time && remaining_bt[i] > 0 &&
remaining_bt[i] < min_bt && flag[i] == 0)
            {
                min_bt = remaining_bt[i];
                shortest = i;
            }
        }
        if (shortest == -1)
        {
            time++;
            continue;
        }
        remaining_bt[shortest]--;
        if (remaining_bt[shortest] == 0)
        {
            completed++;
            flag[shortest] = 1;
            ct[shortest] = time + 1;
            tat[shortest] = ct[shortest] - at[shortest];
            wt[shortest] = tat[shortest] - bt[shortest];
            rt[shortest] = wt[shortest];
        }
```

```
        time++;
    }
}

void displayTable(int n, int at[], int bt[], int ct[], int tat[], int
wt[], int rt[])
{
    printf("\nProcess\tAT\tBT\tCT\tTAT\tWT\tRT\n");
    for (int i = 0; i < n; i++)
    {
        printf("%d\t%d\t%d\t%d\t%d\t%d\t%d\n", i + 1, at[i], bt[i],
ct[i], tat[i], wt[i], rt[i]);
    }
}

int main()
{
    int n;
    printf("Enter number of processes: ");
    scanf("%d", &n);

    int at[n], bt[n], ct[n], tat[n], wt[n], rt[n];
    printf("Enter Arrival Time and Burst Time for each process:\n");
    for (int i = 0; i < n; i++)
    {
        printf("Process %d - Arrival Time: ", i + 1);
        scanf("%d", &at[i]);
        printf("Process %d - Burst Time: ", i + 1);
        scanf("%d", &bt[i]);
    }
    preemptiveSJF(n, at, bt, ct, tat, wt, rt);
    displayTable(n, at, bt, ct, tat, wt, rt);

    return 0;
```

}

Output:

```
Enter number of processes: 4
Enter Arrival Time and Burst Time for each process:
Process 1 - Arrival Time: 0
Process 1 - Burst Time: 8
Process 2 - Arrival Time: 1
Process 2 - Burst Time: 4
Process 3 - Arrival Time: 2
Process 3 - Burst Time: 9
Process 4 - Arrival Time: 3
Process 4 - Burst Time: 5

Process AT      BT      CT      TAT     WT      RT
1       0       8       17      17      9       9
2       1       4       5       4       0       0
3       2       9       26      24      15      15
4       3       5       10      7       2       2
```

Program 2
Question
Write a C program to simulate the following CPU scheduling algorithm to find turnaround time and waiting time.

→ *Priority (pre-emptive & Non-pre-emptive)*

→ *Round Robin (Experiment with different quantum sizes for RR algorithm)*

=> Priority Scheduling (Non-preemptive):
Code
```
#include <stdio.h>
//non-preemptive
void priorityScheduling(int n, int at[], int bt[], int pr[], int ct[],
int tat[], int wt[], int rt[]) {
    int completed = 0, time = 0, min_priority, highest_priority;
    int flag[n];
    for (int i = 0; i < n; i++) {
        flag[i] = 0;
    }
    while (completed < n) {
        min_priority = 9999;
        highest_priority = -1;
        for (int i = 0; i < n; i++) {
            if (at[i] <= time && flag[i] == 0 && pr[i] < min_priority)
{
                min_priority = pr[i];
                highest_priority = i;
            }
        }
        if (highest_priority == -1) {
            time++;
            continue;
        }
        time += bt[highest_priority];
        flag[highest_priority] = 1;
        ct[highest_priority] = time;
        tat[highest_priority] = ct[highest_priority] -
at[highest_priority];
        wt[highest_priority] = tat[highest_priority] -
bt[highest_priority];
        rt[highest_priority] = wt[highest_priority];
        completed++;
    }
}
```

```
void displayTable(int n, int at[], int bt[], int pr[], int ct[], int
tat[], int wt[], int rt[]) {
    printf("\nProcess\tAT\tBT\tPriority\tCT\tTAT\tWT\tRT\n");
    for (int i = 0; i < n; i++) {
        printf("%d\t%d\t%d\t%d\t\t%d\t%d\t%d\t%d\n", i + 1, at[i],
bt[i], pr[i], ct[i], tat[i], wt[i], rt[i]);
    }
}

int main() {
    int n;
    printf("Enter number of processes: ");
    scanf("%d", &n);
    int at[n], bt[n], pr[n], ct[n], tat[n], wt[n], rt[n];
    printf("Enter Arrival Time, Burst Time, and Priority for each
process:\n");
    for (int i = 0; i < n; i++) {
        printf("Process %d - Arrival Time: ", i + 1);
        scanf("%d", &at[i]);
        printf("Process %d - Burst Time: ", i + 1);
        scanf("%d", &bt[i]);
        printf("Process %d - Priority: ", i + 1);
        scanf("%d", &pr[i]);
    }
    priorityScheduling(n, at, bt, pr, ct, tat, wt, rt);
    displayTable(n, at, bt, pr, ct, tat, wt, rt);
    return 0;
}
```

Output:

```
Enter number of processes: 4
Enter Arrival Time, Burst Time, and Priority for each process:
Process 1 - Arrival Time: 0
Process 1 - Burst Time: 4
Process 1 - Priority: 2
Process 2 - Arrival Time: 0
Process 2 - Burst Time: 10
Process 2 - Priority: 1
Process 3 - Arrival Time: 0
Process 3 - Burst Time: 3
Process 3 - Priority: 3
Process 4 - Arrival Time: 0
Process 4 - Burst Time: 12
Process 4 - Priority: 4

Process AT      BT      Priority        CT      TAT     WT      RT
1       0       4       2               14      14      10      10
2       0       10      1               10      10      0       0
3       0       3       3               17      17      14      14
4       0       12      4               29      29      17      17
```

=> Priority Scheduling (Preemptive):

Code

```
#include <stdio.h>

struct Process {
    int id, arrivalTime, burstTime, remainingTime, priority;
    int waitingTime, turnaroundTime, completionTime;
};
int findHighestPriority(struct Process p[], int n, int currentTime) {
    int highest = -1;
    int highestPriority = 1e9;

    for (int i = 0; i < n; i++) {
        if (p[i].arrivalTime <= currentTime && p[i].remainingTime > 0)
{
            if (p[i].priority < highestPriority) {
                highestPriority = p[i].priority;
                highest = i;
            }
        }
    }
    return highest;
}
```

```
void priorityScheduling(struct Process p[], int n) {
    int currentTime = 0, completed = 0;
    float totalWaitingTime = 0, totalTurnaroundTime = 0;
    for (int i = 0; i < n; i++) {
        p[i].remainingTime = p[i].burstTime;
    }
    while (completed < n) {
        int idx = findHighestPriority(p, n, currentTime);

        if (idx == -1) {
            currentTime++;
            continue;
        }

        p[idx].remainingTime--;
        currentTime++;
        if (p[idx].remainingTime == 0) {
            completed++;
            p[idx].completionTime = currentTime;
            p[idx].turnaroundTime = p[idx].completionTime -
p[idx].arrivalTime;
            p[idx].waitingTime = p[idx].turnaroundTime -
p[idx].burstTime;

            totalWaitingTime += p[idx].waitingTime;
            totalTurnaroundTime += p[idx].turnaroundTime;
        }
    }

printf("\nProcess\tArrival\tBurst\tPriority\tCompletion\tTurnaround\t
Waiting\n");
    for (int i = 0; i < n; i++) {
        printf("%d\t%d\t%d\t%d\t\t%d\t\t%d\t\t%d\n", p[i].id,
p[i].arrivalTime, p[i].burstTime,
               p[i].priority, p[i].completionTime,
p[i].turnaroundTime, p[i].waitingTime);
    }

    printf("\nAverage Waiting Time: %.2f", totalWaitingTime / n);
    printf("\nAverage Turnaround Time: %.2f\n", totalTurnaroundTime /
n);
}
int main() {
    int n;
    printf("Enter number of processes: ");
```

```
    scanf("%d",&n);
    struct Process p[n];

    printf("Enter Arrival Time, Burst Time, and Priority (lower
number = higher priority) for each process:\n");
    for (int i = 0; i < n; i++) {
        p[i].id = i + 1;
        printf("Process %d: ", p[i].id);
        scanf("%d %d %d", &p[i].arrivalTime, &p[i].burstTime,
&p[i].priority);
    }
    priorityScheduling(p, n);
    return 0;
}
```

Output:

```
Enter number of processes: 4
Enter Arrival Time, Burst Time, and Priority (lower number = higher priority) for each process:
Process 1: 0
5
2
Process 2: 0
3
1
Process 3: 0
8
3
Process 4: 0
2
4

Process Arrival Burst   Priority        Completion      Turnaround      Waiting
1       0       5       2               8               8               3
2       0       3       1               3               3               0
3       0       8       3               16              16              8
4       0       2       4               18              18              16

Average Waiting Time: 6.75
Average Turnaround Time: 11.25
```

4) Priority sequencing - Preemptive

```
#include <stdio.h>
#include <stdlib.h>

typedef struct {
  int pid;
  int at, bt, priority, ct, tat, wt,
      remaining;
} proc[100];
```

~~void preemptive_priority (proc[],~~

```
void preemptive_priority (int n,
float *avgTaT, float *avgWT){

int completed = 0, time = 0;
int min_index;
int totalTAT = 0;
int total WT = 0;
int isCompleted[n] = {0};

for (int i=0; i<n; i++){
    p[i].remaining = p[i].
                burst;
}
```

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```
while (completed < n) {
    min_index = -1;
    int min_priority = 9999;
    for ( int i = 0 ; i < n ; i++ ) {
        if ( !isCompleted[i] && p[i].at
            <= time && p[i].remaining >0

            if ( p[i] . priority < min_priority
                p[i] . priority == min_priori
                && p[i].at <
                p[min_index].at )) {
                min_priority = p[i].priori
                min_index = i;
            }
        }
    }.
    if (min_index == -1) {
        time++;
        continue;
    }
    p[min_index]. remaining--;
    time++;
    if ( p[min_index]. remaining ==0 {
        p[min_index]. ct = time;
        p[min_index]. tat = p[min_index].
                ct - p[min_index].at;
        p[min_index]. wt = p[min_index]
                tat - p[min_index].bt
        isCompleted[min_index] = 1;
```

```
totalTAT += p[min_index].tat
totalWT += p[min_index].w
completed++;
}
}
* avgTAT = (float)totalTAT/n;
* avgWT = (float) total WT/n;
}
}
```

5) Non Preemptive Priority Scheduling

```
# include <stdio.h>
typedef struct {
        int pid, at, bt, pt, remaining_time,
            tat, wt, time, is_completed
} Process;

void  non preemptive priority ( Process p[],
                int n) {
    int low priority = 9999, selected = -1;
    for ( int i=0; i<n; i++) {
      if ( p[i].at <= time &&
          ! p[i] . is_completed &&
          p[i] . pt < lowpriority ) {

                low priority = p[i].
                selected = i;
      }
   }
```

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```
if (selected == -1) {
        time ++;
        continue;
}
time += p [selected]. bt;
p [selected ], ct = time;
p [selected ] . tat = p [selected ] . ct -
                      p [selected ] . at;
p [selected ] . wt = p [selected ] . tat -
```

=> Round Robin:

Code

```
#include <stdio.h>
void findWaitingTime(int processes[], int n, int bt[], int wt[], int quantum) {
    int rem_bt[n];
    for (int i = 0; i < n; i++) {
        rem_bt[i] = bt[i];
        wt[i] = 0;
        wt++;
    }
    int t = 0;
    while (1) {
        int done = 1;

        for (int i = 0; i < n; i++) {
            if (rem_bt[i] > 0) {
                done = 0;
                if (rem_bt[i] > quantum) {
                    rem_bt[i] -= quantum;
                    //++quantum;
                    t += quantum;
                } else {
                    t += rem_bt[i];
                    wt[i] = t - bt[i];
                    rem_bt[i] = 0;
                }
            }
        }
        if (done) break;
    }
}
```

```
void findTurnAroundTime(int processes[], int n, int bt[], int wt[],
int tat[]) {
    for (int i = 0; i < n; i++) {
        tat[i] = bt[i] + wt[i];
    }
}

void findAvgTime(int processes[], int n, int bt[], int quantum) {
    int wt[n], tat[n];
    findWaitingTime(processes, n, bt, wt, quantum);
    findTurnAroundTime(processes, n, bt, wt, tat);

    int total_wt = 0, total_tat = 0;
    printf("\nProcess\tBurst Time\tWaiting Time\tTurnaround Time\n");
    for (int i = 0; i < n; i++) {
        total_wt += wt[i];
        total_tat += tat[i];
        printf("%d\t%d\t\t%d\t\t%d\n", processes[i], bt[i], wt[i],
tat[i]);
    }
    printf("\nAverage Waiting Time: %.2f", (float)total_wt / n);
    printf("\nAverage Turnaround Time: %.2f\n", (float)total_tat / n);
}

int main() {
    int n, quantum;
    printf("Enter number of processes: ");
    scanf("%d", &n);
    int processes[n];
    int burst_time[n];
    for (int i = 0; i < n; i++) {
        processes[i] = i + 1;
        printf("Enter burst time for process %d: ", i + 1);
```

```
        scanf("%d", &burst_time[i]);
    }
    printf("Enter time quantum: ");
    scanf("%d", &quantum);
    findAvgTime(processes, n, burst_time, quantum);
    return 0;
}
```

Output:

```
Enter number of processes: 4
Enter burst time for process 1: 10
Enter burst time for process 2: 5
Enter burst time for process 3: 7
Enter burst time for process 4: 3
Enter time quantum: 4

Process Burst Time      Waiting Time    Turnaround Time
1       10              15              25
2       5               15              20
3       7               16              23
4       3               12              15

Average Waiting Time: 14.50
Average Turnaround Time: 20.75
```

Program 3

Question

Write a C program to simulate multi-level queue scheduling algorithm considering the following scenario. All the processes in the system are divided into two categories – system processes and user processes. System processes are to be given higher priority than user processes. Use FCFS scheduling for the processes in each queue.

=> Multilevel queue Scheduling

Code

```
#include <stdio.h>
#define TIME_QUANTUM 2
typedef struct {
    int pid, burst_time, arrival_time, queue;
    int waiting_time, turnaround_time, response_time, remaining_time;
```

```
} Process;
void sort_by_arrival(Process p[], int n) {
    Process temp;
    for (int i = 0; i < n - 1; i++) {
        for (int j = i + 1; j < n; j++) {
            if (p[i].arrival_time > p[j].arrival_time) {
                temp = p[i];
                p[i] = p[j];
                p[j] = temp;
            }
        }
    }
}
void round_robin(Process p[], int n, int *time) {
    int done, i;
    do {
        done = 1;
        for (i = 0; i < n; i++) {
            if (p[i].remaining_time > 0) {
                done = 0;
                if (p[i].remaining_time > TIME_QUANTUM) {
                    *time += TIME_QUANTUM;
                    p[i].remaining_time -= TIME_QUANTUM;
                } else {
                    *time += p[i].remaining_time;
                    p[i].waiting_time = *time - p[i].arrival_time -
p[i].burst_time;
                    p[i].turnaround_time = p[i].waiting_time +
p[i].burst_time;
                    p[i].response_time = p[i].waiting_time;
                    p[i].remaining_time = 0;
                }
            }
        }
    } while (!done);
}
void fcfs(Process p[], int n, int *time) {
    for (int i = 0; i < n; i++) {
        if (*time < p[i].arrival_time)
            *time = p[i].arrival_time;
        p[i].waiting_time = *time - p[i].arrival_time;
        p[i].turnaround_time = p[i].waiting_time + p[i].burst_time;
        p[i].response_time = p[i].waiting_time;
        *time += p[i].burst_time;
    }
}
```

```
int main() {
    int n, i, time = 0;
    printf("Enter number of processes: ");
    scanf("%d", &n);

    Process p[n], system_processes[n], user_processes[n];
    int sys_count = 0, user_count = 0;

    for (i = 0; i < n; i++) {
        printf("Enter Burst Time, Arrival Time and Queue of P%d: ", i
+ 1);
        p[i].pid = i + 1;
        scanf("%d %d %d", &p[i].burst_time, &p[i].arrival_time,
&p[i].queue);
        p[i].remaining_time = p[i].burst_time;

        if (p[i].queue == 0)
            system_processes[sys_count++] = p[i];
        else
            user_processes[user_count++] = p[i];
    }
    sort_by_arrival(system_processes, sys_count);
    sort_by_arrival(user_processes, user_count);
    printf("\nQueue 1 is System Process\nQueue 2 is User Process\n");
    round_robin(system_processes, sys_count, &time);
    fcfs(user_processes, user_count, &time);
    Process final_list[n];
    int index = 0;
    for (i = 0; i < sys_count; i++)
        final_list[index++] = system_processes[i];
    for (i = 0; i < user_count; i++)
        final_list[index++] = user_processes[i];

    printf("\nProcess\tWaiting Time\tTurn Around Time\tResponse
Time\n");
    float avg_wt = 0, avg_tat = 0, avg_rt = 0;

    for (i = 0; i < n; i++) {
        printf("%d\t%d\t\t%d\t\t\t%d\n", final_list[i].pid,
final_list[i].waiting_time, final_list[i].turnaround_time,
final_list[i].response_time);
        avg_wt += final_list[i].waiting_time;
        avg_tat += final_list[i].turnaround_time;
        avg_rt += final_list[i].response_time;
    }
    avg_wt /= n;
```

```
    avg_tat /= n;
    avg_rt /= n;
    float throughput = (float)n / time;
    printf("\nAverage Waiting Time: %.2f", avg_wt);
    printf("\nAverage Turn Around Time: %.2f", avg_tat);
    printf("\nAverage Response Time: %.2f", avg_rt);
    printf("\nThroughput: %.2f", throughput);
    return 0;
}
```

Output:

```
Enter number of processes: 4
Enter Burst Time, Arrival Time and Queue of P1: 2
0
1
Enter Burst Time, Arrival Time and Queue of P2: 1
0
2
Enter Burst Time, Arrival Time and Queue of P3: 5
0

1
Enter Burst Time, Arrival Time and Queue of P4: 3
0

2

Queue 1 is System Process
Queue 2 is User Process

Process Waiting Time    Turn Around Time        Response Time
1       0               2                       0
2       2               3                       2
3       3               8                       3
4       8               11                      8

Average Waiting Time: 3.25
Average Turn Around Time: 6.00
Average Response Time: 3.25
Throughput: 0.36
```

METRO
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```
void multilevel_priority_scheduling(
    system_queue, user_queue, sys_count,
    user_count, time_Quantum, * lin ,
                                    at [], bq
{

    sort(user_queue, user_count);
    rr(system_queue, sys_count, TIME_
        QUANT, &time);
    fcfs(user_queue, user_count, &time);

}
```

O/P->

Process	AT	BT	Queue	WT	TAT	RT
P1	0	2	1	0	2	0
P2	0	1	2	2	7	2
P3	0	5	1	7	8	7
P4	0	3	2	8	11	8

Avg WT : 4.25
Avg TAT : 7
Avg RT : 4.25

Multi Level Queue Scheduling

```
# define MAX_PROCESSES 10
# define TIME_QUANTUM 2

typedef struct {
    int at, bt, queue_type, wt,
        tat, rt, rem_time;
} Process;

void rr (Process processes[], int n,
        int time_quantum, int * ti

    int done, i;
```

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```
do{
    done = 1;
    for (i=0; i<n; i++) {
        if(processes[i].rem_time >0);
            done =0;
            if(processes[i].rem_time >
                time_quantum) {

                *time += time_quan
                processes[i].rem_ti
                    -= time_quan;
            }else {

                *time += processes[i]
                    .rem_time;
                processes[i].wt = *tim
                    -processes[i].at
                    processes[i].bt

                processes[i].tat = *time -
                    processes[i].at;
                processes[i].rt =
                    processes[i].wt;
                processes[i].rem_time =0;
            }
        }
    } while (!done);
}
```

```
void fcfs( process processos [], int n,
              int * tim ){
   for (int i=0; i< n; i++) {
        if( *tim < processes [i].at ){
             * tim = proprocessos [i] .at
        }
        processes[i].wt = * tim - processos[i]
        processos [i].tat = processes [i] .wt +
                            processes[i]. bt;
        * time += processes [i]. bt;
   }
}


void sort ( user_quen , user_cou ){
  for( int i= 0; i< user_count - 1; i++){
    for( int j=0; j< user_round - i -1 ;j++){

        if( user_quen [j]. at >
            user_quen [j+1].at ){

             Process temp = user_quen [j];
             user_quen [j] = user_quen [j+1];
             user_quen [j+1 ]= temp;
        }
    }
}
```

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```
void multilevel_priority_scheduling(
    system_queue, user_queue, sys_count,
    user_count, time_Quantum, * tim,
    {                                   at [], bt[]

    sort(user_queue, user_count);
    rr(system_queue, sys_count, TIME_
         QUANT, &time);
    fcfs(user_queue, user_count, &time);

    }
```

O/P->

Process	AT	BT	Queue	WT	TAT	RT
P1	0	2	1	0	2	0
P2	0	1	2	2	7	2
P3	0	5	1	7	8	7
P4	0	3	2	8	11	8

Avg WT : 4.25
Avg TAT : 7
Avg RT : 4.25

Program 4
Question
Write a C program to simulate Real-Time CPU Scheduling algorithms:
-> Rate- Monotonic
-> Earliest-deadline First
-> Proportional scheduling

=> Rate Monotonic Scheduling
Code
```
#include <stdio.h>
#include <stdlib.h>
typedef struct {
    int id;
    int period;
    int execution_time;
    int next_deadline;
    int executed;
} Task;

int compare_tasks(const void *a, const void *b) {
    return ((Task *)a)->period - ((Task *)b)->period;
}

void rate_monotonic_scheduling(Task tasks[], int num_tasks, int
total_time) {
    qsort(tasks, num_tasks, sizeof(Task), compare_tasks);

    /*
    for(int i = 0; i < num_tasks; i++)
        printf("Task %d: %d %d\n", tasks[i].id,
tasks[i].execution_time, tasks[i].period);
    */

    for (int i = 0; i < num_tasks; i++)
        tasks[i].next_deadline = tasks[i].period;
    printf("Time\t");
    for (int i = 0; i < num_tasks; i++)
        printf("Task %d\t", tasks[i].id);
    printf("\n");
    for (int current_time = 0; current_time < total_time;
current_time++)
    {
        printf("%d\t", current_time);
        int executed_task = -1;
```

```
        for (int i = 0; i < num_tasks; i++)
        {
            if (current_time % tasks[i].period == 0)
            {
                tasks[i].next_deadline = current_time +
tasks[i].period;
                tasks[i].executed = 0;
            }
            if (current_time < tasks[i].next_deadline)
            {
                if(tasks[i].executed < tasks[i].execution_time)
                {
                    executed_task = i;
                    tasks[i].executed++;
                    break;
                }
            }
        }
        if (executed_task != -1)
        {
            for (int i = 0; i < num_tasks; i++)
            {
                if (i == executed_task) {
                    printf("Exec\t");
                } else {
                    printf("\t");
                }
            }
        } else {
             for (int i = 0; i < num_tasks; i++) {
                printf("\t");
            }
        }
        printf("\n");
    }
}

int main() {
    Task tasks[] = {
        {1, 20, 3},
        {2, 5, 2},
        {3, 10, 2}
    };

    int num_tasks = sizeof(tasks) / sizeof(tasks[0]);
    int total_time = 20;
```

```
    rate_monotonic_scheduling(tasks, num_tasks, total_time);
    return 0;
}
```

Output:

```
Time    Task 2  Task 3  Task 1
0       Exec
1       Exec
2               Exec
3               Exec
4                       Exec
5       Exec
6       Exec
7                       Exec
8                       Exec
9
10      Exec
11      Exec
12
13
14
15      Exec
16      Exec
17
18
19
```

8) Rate Monotonic -

```c
#include <stdio.h>
typedef struct {
    int pid;
    int period;
    int burst;
    int rem;
} Task;

int gcd (int a, int b) {
    return b==0? a: gcd(b, a%b);
}

int lcm (int a, int b) {
    return a*b / gcd(a,b);
}

int findHyperPeriod (Task tasks[], int n)

    int hyper = tasks[0].period;
    for (int i=1; i<n; i++) {
        hyper = lcm (hyper, tasks[i].
                            period);
    }
    return hyper;
}
```

```
void sortbyperiod(Task tasks[], int n){
for(int i=0; i<n; i++){
  for(int j=i+1; j<n; j++){

    if (tasks[i].period >
        tasks[j].period){

        Task tmp= tasks[i];
        tasks[i]= tasks[j];
        tasks[j]= tmp;
    }
  }
  tasks[i].rem= tasks[i].burst;
  }
}

void rateMonotonic(Task tasks[], int n,
        int sim_time){

    printf("\n Rate-Monotonic Scheduli
    printf("Task \t Task \n");
    sortByPeriod(tasks, n);
    for(int time=0; time <sim_time;
        time ++){
        int scheduled= -1;
        for (int i=0; i<n; i++){
           if( time % tasks[i].perioc
              tasks[i].rem= tasks[i
                                 bu
```

```
for (int i=0; i<n; i++) {
    if (tasks[i].remaining >0);
        scheduled = i;
        break;
    }
}

if (scheduled != -1) {
    tasks[scheduled].rem --;
    printf ("%d \t T %d \n",
            time, tasks[scheduled].
}
else { printf ("%d \t Idle \n",
            time);
    }
  }
}

int main() {
  int n;
  printf (" Enter noc. of tasks: ");
  scanf ("%d", &n);

  Task tasks[n];
  for (int i=0; i<n; i++) {
      tasks[i].pid = i+1;
      printf (" Enter period and burst
          time for task T%d: ", i+1)

      scanf ("%d %d", & tasks[i].period,
            & tasks [i]. burst );
  }
```

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```
int sim_time = findHyperPeriod(tasks, n);
printf("Simulation will run for %d
        units (LCM of periods)\n",
            sim_time);

rateMonotonic(tasks, n, time);
return 0;
}
```

=> Earliest Deadline First

Code

```
#include <stdio.h>
#include <stdlib.h>

typedef struct {
    int id;
    int period;
    int execution_time;
    int deadline;
    int executed;
} Task;

int compare_tasks(const void *a, const void *b) {
```

```
    return ((Task *)a)->deadline - ((Task *)b)->deadline;
}

void earliest_deadline_first_scheduling(Task tasks[], int num_tasks,
int total_time) {
    printf("Time\t");
    for (int i = 0; i < num_tasks; i++)
        printf("Task %d\t", tasks[i].id);
    printf("\n");
    for (int current_time = 0; current_time < total_time;
current_time++) {
        printf("%d\t", current_time);
        int executed_task = -1;

        for (int i = 0; i < num_tasks; i++) {
            if (current_time % tasks[i].period == 0) {
                tasks[i].deadline = current_time + tasks[i].period;
                tasks[i].executed = 0;
            }
        }
        qsort(tasks, num_tasks, sizeof(Task), compare_tasks);

        for (int i = 0; i < num_tasks; i++) {
            if (current_time < tasks[i].deadline && tasks[i].executed
< tasks[i].execution_time) {
                executed_task = i;
                tasks[i].executed++;
                break;
            }
        }
        if (executed_task != -1) {
            for (int i = 0; i < num_tasks; i++) {
                if (i == executed_task) {
                    printf("Exec\t");
                } else {
                    printf("\t");
                }
            }
        } else {
            for (int i = 0; i < num_tasks; i++) {
                printf("\t");
            }
        }
        printf("\n");
    }
}
```

```
int main() {
    Task tasks[] = {
        {1, 20, 3, 20, 0},
        {2, 5, 2, 5, 0},
        {3, 10, 2, 10, 0}
//task
    };

    int num_tasks = sizeof(tasks) / sizeof(tasks[0]);
    int total_time = 20;

    earliest_deadline_first_scheduling(tasks, num_tasks, total_time);
    return 0;
}
```

Output:

```
Time    Task 1  Task 2  Task 3
0       Exec
1       Exec
2               Exec
3               Exec
4                       Exec
5               Exec
6       Exec
7                       Exec
8                       Exec
9
10      Exec
11      Exec
12                      Exec
13              Exec
14
15                      Exec
16              Exec
17
18
19
```

Program 5

Question

Write a C program to simulate producer-consumer problem using semaphores

=> Producer Consumer

Code

```
#include <stdio.h>

int x = 1, mutex = 1, full = 0, empty = 3;
void wait(int *S)
{
    (*S)--;
}

void signal(int *S)
{
    (*S)++;
}
void producer()
{
    wait(&mutex);
    if (empty > 0)
    {
        wait(&empty);
        signal(&full);
        printf("Item produced: %d\n", x++);
    } else {
        printf("Buffer is Full\n");
    }
    signal(&mutex);
}
void consumer() {
    wait(&mutex);
    if (full > 0) {
        wait(&full);
        signal(&empty);
        printf("Item Consumed: %d\n", --x);
    } else {
        printf("Buffer is Empty\n");
    }
    signal(&mutex);
}

int main() {
    int ch;
    printf("1. Produce\n2. Consume\n3. Exit\n");
    while (1) {
        printf("Enter Choice: ");
        scanf("%d", &ch);
        switch (ch) {
```

```
            case 1: producer(); break;
            case 2: consumer(); break;
            default: return 0;
    }
}
}
```

Output:

```
1. Produce
2. Consume
3. Exit
Enter Choice: 2
Buffer is Empty
Enter Choice: 2
Buffer is Empty
Enter Choice: 2
Buffer is Empty
Enter Choice: 2
Buffer is Empty
Enter Choice: 2
Buffer is Empty
Enter Choice: 2
Buffer is Empty
Enter Choice: 1
Item produced: 1
Enter Choice: 1
Item produced: 2
Enter Choice: 1
Item produced: 3
Enter Choice: 1
Buffer is Full
Enter Choice: 1
Buffer is Full
Enter Choice: 2
Item Consumed: 3
Enter Choice: 2
Item Consumed: 2
Enter Choice: 2
Item Consumed: 1
Enter Choice: 2
Buffer is Empty
Enter Choice:

2
Buffer is Empty
Enter Choice: 2
Buffer is Empty
Enter Choice: 3
```

20) Producer Consumer

```
# include <stdio.h>
int mutex = 1, full = 0, x = 0, empty = 3;
int wait (int * s) {
        return (--(* s)); }

int signal (int * s)  return (++(* s));

void producer() {
    wait (& mutex);
    signal (& full);
    wait (& empty);
    x++;
    printf ("Item produced is %d \n", x);
    signal (& mutex);
  }

void consumer() {
    wait (& mutex);
    wait (& full);
    signal (& empty);
    printf (" Consumed item %d \n", x);
    x--;
    signal (& mutex);
}
```

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```
int main() {
  int choice;
  do {
    printf("Enter choice:\n");
    scanf("%d", &choice);
    switch (choice) {
      case 1:
        if((mutex==1)&&
          (empty!=0)) {
            producer(); }

        else printf("Buffer is full");
        ;
        break;

      case 2:
        if (mutex ==1) &&
            (full !=0)) {
            consumer(); }
        else printf("Buffer is empty")
        break;
      case 3:
        printf(" Exiting \n");
        break;
  while (choice !=3);
  return 0;
```

O/P →

Enter your choice : 1
Produced item : 1
Enter your choice : 2
Consumer item : 0
Enter your choice : 3
Exiting.

Program 6

Question

Write a C program to simulate the concept of Dining Philosophers problem.

=> Dining Philosophers

Code

```
//PTHRED AND SEMAPHORE LIBRARY ONLY WORK IN CODEBLOCKS, NOT VSC

#include <pthread.h>
#include <semaphore.h>
#include <stdio.h>
#include <unistd.h>

#define N 5
#define THINKING 2
#define HUNGRY 1
#define EATING 0
#define LEFT (phnum + 4) % N
#define RIGHT (phnum + 1) % N

int state[N];
```

```
int phil[N] = {0, 1, 2, 3, 4};

sem_t mutex;
sem_t S[N];

void test(int phnum) {
    if   (state[phnum]   ==   HUNGRY   &&   state[LEFT]   !=   EATING   &&
state[RIGHT] != EATING) {
        state[phnum] = EATING;
        sleep(2);
        printf("Philosopher  %d  takes  fork  %d  and  %d\n",  phnum  +  1,
LEFT + 1, phnum + 1);
        printf("Philosopher %d is Eating\n", phnum + 1);
        sem_post(&S[phnum]);
    }
}
void take_fork(int phnum) {
    sem_wait(&mutex);
    state[phnum] = HUNGRY;
    printf("Philosopher %d is Hungry\n", phnum + 1);
    test(phnum);

    sem_post(&mutex);
    sem_wait(&S[phnum]);
    sleep(1);
}
void put_fork(int phnum) {
    sem_wait(&mutex);

    state[phnum] = THINKING;
    printf("Philosopher %d putting fork %d and %d down\n", phnum + 1,
LEFT + 1, phnum + 1);
    printf("Philosopher %d is thinking\n", phnum + 1);

    test(LEFT);
    test(RIGHT);

    sem_post(&mutex);
}

void* philosopher(void* num) {
    while (1) {
        int* i = (int*)num;
        sleep(1);
        take_fork(*i);
        sleep(0);
```

```
        put_fork(*i);
    }
}

int main() {
    int i;
    pthread_t thread_id[N];
    sem_init(&mutex, 0, 1);
    for (i = 0; i < N; i++) {
        sem_init(&S[i], 0, 0);
    }
    for (i = 0; i < N; i++) {
        pthread_create(&thread_id[i],        NULL,        philosopher,
(void*)&phil[i]);
        printf("Philosopher %d is thinking\n", i + 1);
    }
    for (i = 0; i < N; i++) {
        pthread_join(thread_id[i], NULL);
    }

    return 0;
}
```

Output:

C:\Users\Admin\Documents\t

```
Philosopher 4 is Hungry
Philosopher 5 putting fork 4 and 5 down
Philosopher 5 is thinking
Philosopher 4 takes fork 3 and 4
Philosopher 4 is Eating
Philosopher 1 is Hungry
Philosopher 3 is Hungry
Philosopher 2 putting fork 1 and 2 down
Philosopher 2 is thinking
Philosopher 1 takes fork 5 and 1
Philosopher 1 is Eating
Philosopher 5 is Hungry
Philosopher 4 putting fork 3 and 4 down
Philosopher 4 is thinking
Philosopher 3 takes fork 2 and 3
Philosopher 3 is Eating
Philosopher 2 is Hungry
Philosopher 1 putting fork 5 and 1 down
Philosopher 1 is thinking
Philosopher 5 takes fork 4 and 5
Philosopher 5 is Eating
Philosopher 4 is Hungry
Philosopher 3 putting fork 2 and 3 down
Philosopher 3 is thinking
Philosopher 2 takes fork 1 and 2
Philosopher 2 is Eating
Philosopher 1 is Hungry
Philosopher 5 putting fork 4 and 5 down
Philosopher 5 is thinking
Philosopher 4 takes fork 3 and 4
Philosopher 4 is Eating
Philosopher 2 putting fork 1 and 2 down
Philosopher 2 is thinking
Philosopher 1 takes fork 5 and 1
Philosopher 1 is Eating
Philosopher 3 is Hungry
Philosopher 5 is Hungry
Philosopher 4 putting fork 3 and 4 down
Philosopher 4 is thinking
```

9) Dining Philosopher

```
# include <pthread.h>
# include <semaphore.h>
# include <stdio.h>
# define N 5
# define THINKING 2
# define HUNGRY 1
# define EATING 0
# define LEFT (phnum + 4)% N
# define RIGHT (phnum + 1)% N

int state [N];
int phil [N] = {0, 1, 2, 3, 4};
sem_t mutex;
sem_t S[N];

int main () {
int i;
pthread_t thread_id [N];
sem_init (& mutex, 0, 1);
for (i = 0; i < N; i++)
    sem_init (& S[i], 0, 0);

for (i = 0; i < N; i++) {
    pthread_create (& thread_id [i],
        NULL, philospher, & phil [i]);
    printf (" Philosopher %d is
        thinking \n", i + 1);
}
```

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```
for (i=0; i<N; i++)
    pthread_join (thread_id[i], NULL);
}

void test (int phnum) {
    if (state [phnum] == HUNGRY &&
        state [LEFT] != EATING &&
        state [RIGHT] != EATING) {

        state [phnum] = EATING;
        sleep(2);
        printf ("Philosopher %d takes
            fork %d and %d \n",
            phnum+1, LEFT+1,
            phnum+1);
        printf ("Philosopher %d is
                EATING \n", phnum+1);
        sem_post (& S[phnum]);
    }
}

void take_fork (int phnum) {
    sem_wait (& mutex);
    state [phnum] = HUNGRY;
    printf (" Philosopher %d is Hungry \n",
            phnum+1);
    test (phnum);
    sem_post (& mutex);
    sem_wait (& S[phnum]);
    sleep (1);
}
```

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```
void put_fork( int phnum) {
    sem_wait (& mutex);
    state [ phnum ] = THINKING;
    printf ("Philosopher %d putting
             fork %d and %d
             down \n",
          phnum+1, LEFT+1, phnum+1
    printf("Philosopher %d is thinking \n",
          phnum +1);
    test (LEFT);
    test (RIGHT);
    sem_post (& mutex);
  }

void * philosopher (void * num) {
  while (1) {
    int * i = num;
    sleep (1);
    take_fork (* i);
    sleep (0);
    put - fork (* i);
  }
}
```

O/P →

Philosophor 0 is thinking.

" 1 "

" 2 "

" 2 finished eating and put down forks.

" 1 is eating

" 2 is thinking

:

Program 7

Question

Write a C program to simulate Bankers algorithm for the purpose of deadlock avoidance.

=> Banker's Algorithm / Deadlock Avoidance

Code

```
#include <stdio.h>
#include <stdlib.h>
int condition(int **need, int *work, int i, int m)
{
    for (int j = 0; j < m; j++)
    {
        if (need[i][j] > work[j])
            return 0;
    }
    return 1;
}
int safety(int m, int n, int **allocated, int **max, int *available,
int *sequence)
{
    // Need Matrix
    int **need = (int**) malloc(n * sizeof(int*));
    for (int i = 0; i < n; i++)
    {
        need[i] = (int*) malloc(m * sizeof(int));
        for (int j = 0; j < m; j++)
        {
            need[i][j] = max[i][j] - allocated[i][j];
        }
    }
    // Work array
    int *work = (int*) malloc(m * sizeof(int));
    for (int i = 0; i < m; i++)
    {
        work[i] = available[i];
    }
    // Finish array
    int *finish = (int*) malloc(n * sizeof(int));
    for (int i = 0; i < n; i++)
    {
        finish[i] = 0;
    }

    int safeIndex = 0;
```

```
    int changed;
    do {
        changed = 0;
        for (int i = 0; i < n; i++)
        {
            if (!finish[i] && condition(need, work, i, m))
            {
                for (int j = 0; j < m; j++)
                {
                    work[j] += allocated[i][j];
                }
                finish[i] = 1;
                sequence[safeIndex++] = i;
                changed = 1;
            }
        }
    } while (changed);

    for (int i = 0; i < n; i++)
    {
        if (!finish[i])
        {
            return 0;
        }
    }
    return 1;
}
int main()
{
    int n, m;
    printf("Enter number of processes and resources (n x m order): ");
    scanf("%d",&n);
    scanf("%d",&m);
    // Allocation Matrix
    printf("Enter Allocation Matrix:\n");
    int **allocated = (int **) malloc(n * sizeof(int*));
    for (int i = 0; i < n; i++)
    {
        allocated[i] = (int*) malloc(m * sizeof(int));
        for (int j = 0; j < m; j++)
        {
            scanf("%d", &allocated[i][j]);
        }
    }

    // Max Matrix
```

```
    printf("Enter Max Matrix:\n");
    int **max = (int **) malloc(n * sizeof(int*));
    for (int i = 0; i < n; i++)
    {
        max[i] = (int*) malloc(m * sizeof(int));
        for (int j = 0; j < m; j++)
        {
            scanf("%d", &max[i][j]);
        }
    }
    // Available Matrix
    printf("Enter Available matrix:\n");
    int *available = (int *) malloc(m * sizeof(int));
    for (int i = 0; i < m; i++)
    {
        scanf("%d", &available[i]);
    }
    // Sequence Matrix
    int *sequence = (int *) malloc(n * sizeof(int));

    int safe = safety(m, n, allocated, max, available, sequence);
    if (safe)
    {
        printf("System is in a Safe State.\nSafe Sequence: ");
        for (int i = 0; i < n; i++)
        {
            printf("P%d\t", sequence[i]);
        }
        printf("\n");
    }
    else
    {
        printf("System is not in a Safe State.\n");
    }
    return 0;
}
```

Output:

```
Enter number of processes and resources (n x m order): 5 3
Enter Allocation Matrix:
0 1 0
2 0 0
3 0 2
2 1 1
0 0 2
Enter Max Matrix:
7 5 3
3 2 2
9 0 2
2 2 2
4 3 3
Enter Available matrix:
3 3 2
System is in a Safe State.
Safe Sequence: P1       P3      P4      P0      P2
```

Q) Banker's Algorithm

```
#include <stdio.h>
#include <stdlib.h>
int condition (int ** need, int * work, int i, int m)
 {
   for(int j = 0; j<m; j++)
   {
      if(need [i][j] > work [j])
       return 0; }
     return 1; }
int* Safety (int m, int n, int ** allocated, int ** max, int* avail,
                                                     int* sequence)
 {
   int ** need = (int**) malloc (n * size of (int *));
   for (int i = 0; i<n; i++)
   {
     need [i] = (int *) malloc (m * size of (int));
     for (int i = 0; i<n; i++)
     {
       need [i] = (int *) malloc (m * sizeof(int));
       for (int j = 0; j<m; j++)
       {
          need [i][j] = max[i][j] - allocated [i][j];
       } }

 int safe index = 0;
 int changed;
 do {
    changed = 0
    for (int i = 0; i<n; i++)
    {
```

```
if (!Finish [i] && condition(need, work, i, m))
 {
   for (int j = 0 ; j < m ; j++)
     {
        work[j] += allocated [i][j]; }
        Finish[i] = 1 ;
        sequence [safeIndex ++] = i;
        changed = 1; } }
 } while (changed);
  for(int i = 0; i < n; i++)
  {
     if (!Finish[i]) {
       return 0; } } return 1; }
int main()
{
  int n, m;
  printf("Enter number of processes and resources (n x m)
                                                   order):"
  scanf ("%d", &n);
  scanf("%d", &m);
  printf ("Enter Allocation Matrix :\n");
   int ** allocated = (int **) malloc (n * size of (int *));
    for (int i = 0; i < n; i++) {
       allocated [i] = (int *) malloc (m * sizeof (int));
         for (int j = 0; j < m; j++){
            scanf ("%d", &allocated [i] [j]); }}
   printf("Enter Max Matrix :\n");
   int **max = (int **) malloc (n * sizeof (int*));
   {
       max [i] = (int *) malloc (m * sizeof(int) );
       for (int i=0; i<n; i++)
     {   max[i] = (int *) malloc (m * sizeof (int));
```

Enter Available matrix
 3   3   2
System is in Safe State
Safe sequence: P1   P3   P4 P0 P2

Program 8

Question

Write a C program to simulate deadlock detection

=> Deadlock Detection

Code

```
#include <stdio.h>
#include <stdbool.h>
#define P 5
#define R 3
int main() {
    int finish[P] = {0};
    int work[R];
    int need[P][R] = {
        {7, 5, 3},
        {3, 2, 2},
        {9, 0, 2},
        {2, 2, 2},
        {4, 3, 3}
    };
    int allocation[P][R] = {
        {0, 1, 0},
        {2, 0, 0},
        {3, 0, 2},
        {2, 1, 1},
        {0, 0, 2}
    };
    int available[R] = {3, 3, 2};
    for (int i = 0; i < R; i++) {
        work[i] = available[i];
    }
    bool deadlock = false;
    int count = 0;

    while (count < P) {
        bool found = false;
        for (int p = 0; p < P; p++) {
            if (finish[p] == 0) {
                bool canFinish = true;
                for (int r = 0; r < R; r++) {
                    if (need[p][r] - allocation[p][r] > work[r]) {
                        canFinish = false;
                        break;
                    }
                }
```

```
                if (canFinish) {
                    for (int r = 0; r < R; r++) {
                        work[r] += allocation[p][r];
                    }
                    printf("Process %d can finish.\n", p);
                    finish[p] = 1;
                    found = true;
                    count++;
                }
            }
        }
        if (!found) {
            deadlock = true;
            break;
        }
    }
    if (deadlock) {
        printf("System is in a deadlock state.\n");
    } else {
        printf("System is not in a deadlock state.\n");
    }
    return 0;
}
```

Output:

```
Process 1 can finish.
Process 3 can finish.
Process 4 can finish.
Process 0 can finish.
Process 2 can finish.
System is not in a deadlock state.
```

6. Deadlock Detection

```
#include <stdio.h>
#include <stdhool.h>
#dctine P 5
#define R 3
int main () {
    int finish [P] = {0};
    int work [R];
    int need [P][R] = {
        {7, 5, 3};
        {3, 2, 2},
        {9, 0, 2},
        {2, 2, 2},
        {4, 3, 3} };
    int allocation [P][R] = {
        {0, 1, 0},
        {2, 0, 0},
        {3, 0, 2},
        {2, 1, 1}
        {0, 0, 2} };
    int available [R] = {3, 3, 2};
    for (int i = 0; i < R; i++) {
        work [i] = available [i]; }
```

```
bool deadlock = false;
int count = 0;
while (count < P) {
    bool found = false;
    for (int p = 0; p < P; p++){
      if (finish [p] == 0) {
        bool canFinish = true;
        for (int r = 0 ; r < R; r++) {
          if (need [p][r] - allocation [p][r]) work
              canFinish = false;
              break;
          }
        }
      if (canFinish){
        for (int r = 0; r < R; r++) {
          work[r] += allocation [p][r]; }
        }
      }}
    if (! found) {
        deadlock = true;
        break;
  }}
  if(deadlock) { printf("System is in deadlock state.\n
  else { printf("System is not in deadlock state.\n
  return 0;
}
```

Output: Process 1 can finish
Process 3 can finish
Process 4 can finish
Process 0 can finish
Process 2 can finish
System is not in a deadlock state

Program 9

Question

Write a C program to simulate the following contiguous memory allocation techniques a) Worst-fit

d) Best-fit

e) First-fit

=> Best fit, worst fit, first fit

Code

```
#include <stdio.h>

struct Block {
    int block_no;
    int block_size;
    int is_free;
};

struct File {
    int file_no;
    int file_size;
};

void bestFit(struct Block blocks[], int n_blocks, struct File files[],
int n_files) {
    printf("Memory Management Scheme - Best Fit\n");

printf("File_no:\tFile_size:\tBlock_no:\tBlock_size:\tFragment\n");

    for (int i = 0; i < n_files; i++) {
        int best_fit_block = -1;
        int min_fragment = 10000; // Initialize with a large value

        for (int j = 0; j < n_blocks; j++) {
            if (blocks[j].is_free && blocks[j].block_size >=
files[i].file_size) {
                int fragment = blocks[j].block_size -
files[i].file_size;
                if (fragment < min_fragment) {
                    min_fragment = fragment;
                    best_fit_block = j;
                }
            }
        }

        if (best_fit_block != -1) {
```

```
            blocks[best_fit_block].is_free = 0;
            printf("%d\t\t%d\t\t%d\t\t%d\t\t%d\n", files[i].file_no,
files[i].file_size,
                   blocks[best_fit_block].block_no,
blocks[best_fit_block].block_size, min_fragment);
        }
    }
}

void firstFit(struct Block blocks[], int n_blocks, struct File
files[], int n_files) {
    printf("Memory Management Scheme - First Fit\n");

printf("File_no:\tFile_size:\tBlock_no:\tBlock_size:\tFragment\n");

    for (int i = 0; i < n_files; i++) {
        int found = 0;
        for (int j = 0; j < n_blocks; j++) {
            if (blocks[j].is_free && blocks[j].block_size >=
files[i].file_size) {
                blocks[j].is_free = 0;
                int fragment = blocks[j].block_size -
files[i].file_size;
                printf("%d\t\t%d\t\t%d\t\t%d\t\t%d\n",
files[i].file_no, files[i].file_size,
                       blocks[j].block_no, blocks[j].block_size,
fragment);
                found = 1;
                break;
            }
        }
        if (!found) {
            printf("No suitable block found for File %d\n",
files[i].file_no);
        }
    }
}

void worstFit(struct Block blocks[], int n_blocks, struct File
files[], int n_files) {
    printf("Memory Management Scheme - Worst Fit\n");

printf("File_no:\tFile_size:\tBlock_no:\tBlock_size:\tFragment\n");

    for (int i = 0; i < n_files; i++) {
        int worst_fit_block = -1;
```

```
        int max_fragment = -1; // Initialize with a small value

        for (int j = 0; j < n_blocks; j++) {
            if (blocks[j].is_free && blocks[j].block_size >=
files[i].file_size) {
                int fragment = blocks[j].block_size -
files[i].file_size;
                if (fragment > max_fragment) {
                    max_fragment = fragment;
                    worst_fit_block = j;
                }
            }
        }

        if (worst_fit_block != -1) {
            blocks[worst_fit_block].is_free = 0;
            printf("%d\t\t%d\t\t%d\t\t%d\t\t%d\n", files[i].file_no,
files[i].file_size,
                   blocks[worst_fit_block].block_no,
blocks[worst_fit_block].block_size, max_fragment);
        }
    }
}

int main() {
    int n_blocks, n_files;
    printf("Enter the number of blocks: ");
    scanf("%d", &n_blocks);
    printf("Enter the number of files: ");
    scanf("%d", &n_files);

    struct Block blocks[n_blocks];
    for (int i = 0; i < n_blocks; i++) {
        blocks[i].block_no = i + 1;
        printf("Enter the size of block %d: ", i + 1);
        scanf("%d", &blocks[i].block_size);
        blocks[i].is_free = 1;
    }

    struct File files[n_files];
    for (int i = 0; i < n_files; i++) {
        files[i].file_no = i + 1;
        printf("Enter the size of file %d: ", i + 1);
        scanf("%d", &files[i].file_size);
    }
    while(1) {
```

```
    int choice;
    printf("Choose Memory Management Scheme:\n");
    printf("1. Best Fit\n");
    printf("2. First Fit\n");
    printf("3. Worst Fit\n");
    printf("[ANY KEY]. Exit\n");
    printf("Enter your choice: ");
    scanf("%d", &choice);

    // Reset blocks for allocation scheme
    for (int i = 0; i < n_blocks; i++) {
        blocks[i].is_free = 1;
    }

    switch (choice) {
        case 1:
            bestFit(blocks, n_blocks, files, n_files);
            break;
        case 2:
            firstFit(blocks, n_blocks, files, n_files);
            break;
        case 3:
            worstFit(blocks, n_blocks, files, n_files);
            break;
        default:
        printf("Closing...");
            return 0;
    } }

    return 0;
}
```

Output:

```
Enter the number of blocks: 5
Enter the number of files: 4
Enter the size of block 1: 100
Enter the size of block 2: 500
Enter the size of block 3: 200
Enter the size of block 4: 300
Enter the size of block 5: 600
Enter the size of file 1: 212
Enter the size of file 2: 417
Enter the size of file 3: 112
Enter the size of file 4: 426
Choose Memory Management Scheme:
1. Best Fit
2. First Fit
3. Worst Fit
[ANY KEY]. Exit
Enter your choice: 1
Memory Management Scheme - Best Fit
File_no:        File_size:      Block_no:       Block_size:     Fragment
1               212             4               300             88
2               417             2               500             83
3               112             3               200             88
4               426             5               600             174
Choose Memory Management Scheme:
1. Best Fit
2. First Fit
3. Worst Fit
[ANY KEY]. Exit
Enter your choice: 2
Memory Management Scheme - First Fit
File_no:        File_size:      Block_no:       Block_size:     Fragment
1               212             2               500             288
2               417             5               600             183
3               112             3               200             88
No suitable block found for File 4
Choose Memory Management Scheme:
1. Best Fit
2. First Fit
3. Worst Fit
[ANY KEY]. Exit
Enter your choice: 5
Closing...
```

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17) Best Fit

```
void best fit ( struct Block blocks[ ],
                int n_blocks,
                struct File files[ ],
                int n_files) {

    for(int i=0; i < n_files; i++) {
        int best_fit_block = -1;
        int min_fragment = 10000;
        for (int j = 0; j < n_blocks; j++)
          if (blocks[j]. is_free &&
              blocks[j]. block_size >=
              files[i]. file_size) {

              if (fragment < min_fragment)
                  min_fragment = fragme
                  best_fit_block = j;
              }
          }
      }
  if(best_fit_block != -1) {
      blocks[best_fit_block]. is_free =
      printf("%d \t %d \t %d \t
              files[i]. file_no,
              files[i]. file_size,
              blocks[best_fit_block]
                block_no,
              blocks[best_fit_block]
                block_size,
              min_fragment);
```

```
else printf("%d\t%d\t
        Not Allocated", files[i].file_no,
                        files[i].file_size);
    }
  }
}
```

O/P →

File_no	File_size	Block_no	Block_size	Fragment
1	212	3	300	88
2	146	4	200	54
3	426	2	500	74
4	404	N/A	N/A	N/A

11) First Fit

```
# include <stdio.h>
struct Block {
    int block_no;
    int block_size;
    int is_free;
  }
struct File {
    int file_no;
    int file_size;
  }

void first Fit ( struct Block blocks [],
       int n_blocks,
       struct File file [],
       int n_file) {

    printf ("\n First Fit ");
    for (int i=0; i < n_files; i++){
        int allocated=0;
        for (int j=0; j < n_blocks; j++){
            if (blocks[j]. is_free &&
                blocks[j]. block_size >=
                files [i]. file_size ) {

                int fragment = blocks[j].
                    block_size - files [i].
                                 file_size
            blocks[j]. is_free=0;
```

```
printf("%d\t %d\t%d\t%d\t...",
       files[i].file_no,
       files[i].file_size,
       blocks[j].block_no,
       blocks[j].block_size,
       fragment);
    allocated = 1;
    break;
   }
  }
  if(!allocated) {
     printf("%d\t%d\t Not
          Allocated \n",
          files[i].file_no,
          files[i].file_size);
   }
  }
 }
```

13) Worst fit

```
void woorst fit ( struct Block blocks[],
                  int n_blocks,
                  struct File files[],
                  int n_files) {

for (int i=0; i < n_files; i++) {
    int worst_fit_block = -1;
    int max_fragment = -1;
    for (int j=0; j < n_block; j++) {
      if (blocks[j]. is free &&
          blocks[j]. block_size >=
            files[i]. file_size) {

            int fragment = blocks[j] . block_s
                        - files [i] . file_siz
            if (frament > max_fragment) {
               max_fragment = fragment;
               worst_fit_block = j;
            }
       }
   }
if (worst_fit_block != -1) {
   blocks[worst_fit_block]. is_free
   printf("\n%d \t %d \t %d \t
          files [i]. file_no,
          files [i]. file_size,
```

```
        blocks[worst_fit_block].block_no,
        blocks[worst_fit_block].block_size,
        max_fragment);
        } else {
            printf("%d\t%d\t Not Allocated\n",
                files[i].file_no,
                files[i].file_size);
    }
  }
}
```

Program 10

Question

Write a C program to simulate page replacement algorithms a) FIFO
d) LRU
e) Optimal

=> LRU & Optimal

Code

```
#include <stdio.h>
#include <stdlib.h>

int search(int key, int frame[], int frameSize) {
    for (int i = 0; i < frameSize; i++) {
        if (frame[i] == key)
            return i;
    }
    return -1;
}

int findOptimal(int pages[], int frame[], int n, int index, int
frameSize) {
    int farthest = index, pos = -1;
    for (int i = 0; i < frameSize; i++) {
        int j;
        for (j = index; j < n; j++) {
            if (frame[i] == pages[j]) {
                if (j > farthest) {
                    farthest = j;
                    pos = i;
                }
                break;
            }
        }
        if (j == n)
            return i;
    }
    return (pos == -1) ? 0 : pos;
}

void simulateFIFO(int pages[], int n, int frameSize) {
    int frame[frameSize], front = 0, count = 0, hits = 0;

    for (int i = 0; i < frameSize; i++)
        frame[i] = -1;
```

```
    for (int i = 0; i < n; i++) {
        if (search(pages[i], frame, frameSize) == -1) {
            frame[front] = pages[i];
            front = (front + 1) % frameSize;
            count++;
        } else {
            hits++;
        }
    }
    printf("FIFO Page Faults: %d, Page Hits: %d\n", count, hits);
}

void simulateLRU(int pages[], int n, int frameSize) {
    int frame[frameSize], time[frameSize], count = 0, hits = 0;

    for (int i = 0; i < frameSize; i++) {
        frame[i] = -1;
        time[i] = 0;
    }

    for (int i = 0; i < n; i++) {
        int pos = search(pages[i], frame, frameSize);
        if (pos == -1) {
            int least = 0;
            for (int j = 1; j < frameSize; j++) {
                if (time[j] < time[least])
                    least = j;
            }
            frame[least] = pages[i];
            time[least] = i;
            count++;
        } else {
            hits++;
            time[pos] = i;
        }
    }
    printf("LRU Page Faults: %d, Page Hits: %d\n", count, hits);
}

void simulateOptimal(int pages[], int n, int frameSize) {
    int frame[frameSize], count = 0, hits = 0;

    for (int i = 0; i < frameSize; i++)
        frame[i] = -1;
```

```
    for (int i = 0; i < n; i++) {
        if (search(pages[i], frame, frameSize) == -1) {
            int index = -1;
            for (int j = 0; j < frameSize; j++) {
                if (frame[j] == -1) {
                    index = j;
                    break;
                }
            }
            if (index != -1) {
                frame[index] = pages[i];
            } else {
                int replaceIndex = findOptimal(pages, frame, n, i + 1,
frameSize);
                frame[replaceIndex] = pages[i];
            }
            count++;
        } else {
            hits++;
        }
    }
    printf("Optimal Page Faults: %d, Page Hits: %d\n", count, hits);
}

int main() {
    int n, frameSize;
    printf("Enter the size of the pages: ");
    scanf("%d", &n);

    int pages[n];
    printf("Enter the page strings: ");
    for (int i = 0; i < n; i++)
        scanf("%d", &pages[i]);

    printf("Enter the no of page frames: ");
    scanf("%d", &frameSize);

    simulateFIFO(pages, n, frameSize);
    simulateOptimal(pages, n, frameSize);
    simulateLRU(pages, n, frameSize);

    return 0;
}
```

Output:

```
Enter the size of the pages: 7
Enter the page strings: 1 3 0 3 5 6 3
Enter the no of page frames: 3
FIFO Page Faults: 6, Page Hits: 1
Optimal Page Faults: 5, Page Hits: 2
LRU Page Faults: 5, Page Hits: 2
```

14) FIFO

```
int search (int key, int fram [],
            int size) {
  for (int i=0; i <size ; i++) {
       if (frame [i] ==key) return 1;
  }
  return 0;
}


void fifo (int pages [], int n,
           int frames []) {

int frame [framesize ], front =0 , faults =0, hit =0
for (int i=0 ; i < framesize ; i++) {
        frame [i] = -1; }
for (int i=0 ; i <n; i++) {
     if (! search (pages [i], fram,
                         framesize)) {

          frame [front ]= pages[i];
          front = (front +1) % framesize;
          faults ++;
     }
     else hits ++;
  }
printf ("Faults %d , Hits %d",
          faults, hits);
}
```

O/P →

Enter the size of page : 7

Enter the page strings : 1 3 0 3 5 6 3

FIFO Faults : 6 Hits : 1

15) LRU and optimal

```
int findoptimal( int pages[], int frames[],
        int n, int index,
        int framesize) {
int farthest = index , pos = -1;
for (int i=0; i < framesize; i++) {
    int j;
    for (j = index; j < n; j++) {
        if ( frame [i] == pages [j]) {
            if (j > farthest) {
                farthest = j;
                pos = i;
            }
        break;
        }
    }
    if (j==n) return i;
}
return (pos == 0) ? 0 : pos;
}

void simulate lru (int pages [], int n,
        int framesize ) {

    int frame [framesize], time [framesize],
        count =0, hits =0;
```

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```
for (int i=0; i < framesize; i++){
    frame[i] = -1;
    time[i] = 0;  }

for (int i=0; i<n; i++) {
    int pos = search (pages[i],
               frame, framesize);
    if (pos == -1){
        int least = 0;
        for (int j= 1; j< framesize;
                j++) {
            if (time[j] < time[least])
                least = j ;
        }
        frame[least] = pages[i];
        time[least] = i;
        count++;
    }
    else { hits ++;
        time[pos] = i; }
}
printf("LRU faults %d , hits %d",
        count, hits); }
```

```
void stimulate optimal (int pages, int n,
        int frame size) {

int frame [ frame size ], count = 0, hits = 0;
for (int i = 0; i < frame size; i++) {
        frame[i] = -1;
    }
for (int i = 0; j < n; i++) {
    if (search (pages[i], frame, frame size)
        {
        int index = -1;
        for (int j = 0; j < frame size; j++) {
          if (frame [j] == -1) {
                index = j;
                break;
            }
        }
      if (index != -1) frame [index] =
                                   pages[i];

            int index = -1;
            for ( int j = 0; j<frame size; j++) {
                if (frame [j] == -1) {
                    index = j;
                    break;
                }
            }
        if (index != -1) {
            frame [index] = pages[i];
```

```
        else {
            int replaceindex = findoptimal( pages,
                        frame, n, i, framesize);
            frame [replacementindex] = pages[i];
            }
        count ++; }
    else { hits ++; }
}
printf ("Optimal faults %d, hits %d",
              count, hits);

}
```

O/P →

Enter the size : 12

Enter page string : 7 0 1 2 0 3 0 4 2 3

Enter no. of frames : 3

Optimal Faults : 7 , Hits : 5

LRU Faults : 9, Hits : 3