LABORATORY MANUAL

Operating System Lab
[KCS-451]

Department of Computer Science & Engineering

SHRI RAMSWAROOP MEMORIAL GROUP OFPROFESSIONAL COLLEGES, LUCKNOW

Course: B.Tech.
Year II Semester IV

AFFILIATED TO

Dr. APJ ABDUL KALAM TECHNICAL UNIVERSITY, LUCKNOW

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RAMSWAROOP
MEMORIAL GROUP OF PROFESSIONAL COLLEGES

An ISO 9001:2008 Certified College
Governed by SRMIMCA
(Affiliated to Dr. A. P. J. Abdul Kalam Technical University, Lucknow, Approved by AICTE, New Delhi)

OUR VISION

To achieve international standards in value based professional education for the benefit of society and the nation.

OUR MISSION

- To dedicate teaching, learning, and collaborating in pursuit of frontier technologies with a spirit of innovation and excellence.
- To foster human values and ethos, compassion for ecosystem and obligation towards society and the nation.
- To provide an environment conducive to continuous learning, and all-round development of college fraternity.

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

VISION

To become a world class seat of learning in Computer Science to produce competent software professionals with strong values and dedication to the nation.

MISSION

M1: To produce competent Computer Science professionals through quality education.

M2: To inculcate social and ethical values in students for the wellbeing of the nation.

M3: To encourage exploration of cutting-edge technologies and pursuance of lifelong learning.

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Program Outcomes (POs)

POs describe what the students are expected to know and would be able to do upon the graduation as a professional engineer. These are various graduate attributes that relate to the skills, knowledge, competence, and behaviour that students acquire at the end of engineering programme. The POs adopted by NBA for UG Engineering Programme are given below:

PO-01 Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO-02 Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO-03 Design/Development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO-04 Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions for complex problems.

PO-05 Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO-06 The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO-07 Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO-08 Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO-09 Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO-10 Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO-11 Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO-12 Lifelong learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

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Prof. (Col.) H.K. Jaiswal
Director General
Shri Ramswaroop Memorial Group of
Professional Colleges, Lucknow

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

PROGRAMME SPECIFIC OUTCOME

PS01: Quick Learner: Ability to learn and adapt quickly in the rapidly changing and ever evolving field of computer science.

PS02: Proficiency in software: To be deft and well versed with various standard and open source software.

PROGRAM EDUCATIONAL OBJECTIVE

PE01: To have sound knowledge in mathematical, scientific and engineering concepts to formulate, design, analyze, and solve engineering problems so as to be ready for corporate world, higher education and research.

PE02: To be technically competent, and quick to adapt the technological advancements to remain current in the profession.

PE03: To be deft in working as a team player in a multidisciplinary- multifunctional environment.

PE04: To be ethical, humane and socially committed computer engineer having empathy for the society.

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Do's and Don't

Do's:-

1) Entry of student should be made with terminal number.
2) Student must enter the lab in uniform.
3) Properly shut down the system before leaving.
4) Student should arrange the chair after leaving.
5) Student must maintain discipline in the lab.
6) Printing schedule should be followed.
7) Student should come with proper study material in labs.

Don't:-

1) Spitting, smoking and chewing is not allowed.
2) Student should not play games in the computer.
3) Use of mobile is strictly prohibited in the lab.
4) Do not come with bags and baggage in the lab.
5) Do not install the software without permission.
6) Do not insert pen drive in computer without permission.

Lab Instructor/ Lab Incharge

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Course Outcome (CO) : At the end of course , the student will be able to:

CO1: Understand and implement basic services and functionalities of the operating system using system calls.

CO2: Use modern operating system calls and synchronization libraries in software/ hardware interfaces.

CO3: Analyze and simulate CPU Scheduling Algorithms like FCFS, Round Robin, SJF, and Priority.

CO4: Implement memory management schemes and page replacement schemes and simulate file allocation and organization techniques.

CO5: Understand the concepts of deadlock in operating systems and implement them in multiprogramming system.

Prepared By
Er. AKANSHA SINGH

Approved By
HOD (CSE)

ASSESSMENT SHEET

S. No	Experiment Name	Date of Issue	Date of Done	Date of Check	Marks Obtained	Faculty Signature
1	Study of hardware and software requirements of different operating systems (UNIX,LINUX,WINDOWS XP, WINDOWS7/8					
2	Execute various UNIX system calls for iv. Process management v. File management vi. Input/output Systems calls					
3	Implement CPU Scheduling Policies: iii. SJF iv. FCFS					
4	Implement CPU Scheduling Policies: i. Priority ii. Round robin					
5	Write a C program to simulate Bankers algorithm for the purpose of deadlock avoidance.					
6	Implement file storage allocation technique: iv. Contiguous(using array) v. Linked –list(using linked-list) vi. Indirect allocation (indexing)					
7	Calculation of external and internal fragmentation.					
8	Implementation of contiguous allocation techniques: iv. Worst-Fit v. Best- Fit vi. First- Fit					
9	Implement the solution for Bounded Buffer (producer-consumer)					

	problem using inter process communication techniques-Semaphores.					
10	Implementation of resource allocation graph RAG					

INTRODUCTION

An operating system acts as an intermediary between the user of a computer and computer hardware. The purpose of an operating system is to provide an environment in which a user can execute programs in a convenient and efficient manner.

An operating system is software that manages computer hardware. The hardware must provide appropriate mechanisms to ensure the correct operation of the computer system and to prevent user programs from interfering with the proper operation of the system.

Operating System – Definition:

- An operating system is a program that controls the execution of application programs and acts as an interface between the user of a computer and the computer hardware.
- A more common definition is that the operating system is the one program running at all times on the computer (usually called the kernel), with all else being application programs.
- An operating system is concerned with the allocation of resources and services, such as memory, processors, devices, and information. The operating system correspondingly includes programs to manage these resources, such as a traffic controller, a scheduler, a memory management module, I/O programs, and a file system.

Functions of Operating system – Operating system performs three functions:

1. **Convenience:** An OS makes a computer more convenient to use.
2. **Efficiency:** An OS allows the computer system resources to be used efficiently.
3. **Ability to Evolve:** An OS should be constructed in such a way as to permit the effective development, testing, and introduction of new system functions at the same time without interfering with service.

The operating system as User Interface –

User

1. System and application programs
2. Operating system
3. Hardware

Every general-purpose computer consists of the hardware, operating system, system programs, and application programs. The hardware consists of memory, CPU, ALU, and I/O devices, peripheral devices, and storage devices. System program consists of compilers, loaders, editors, OS, etc. The application program consists of business programs, database programs.

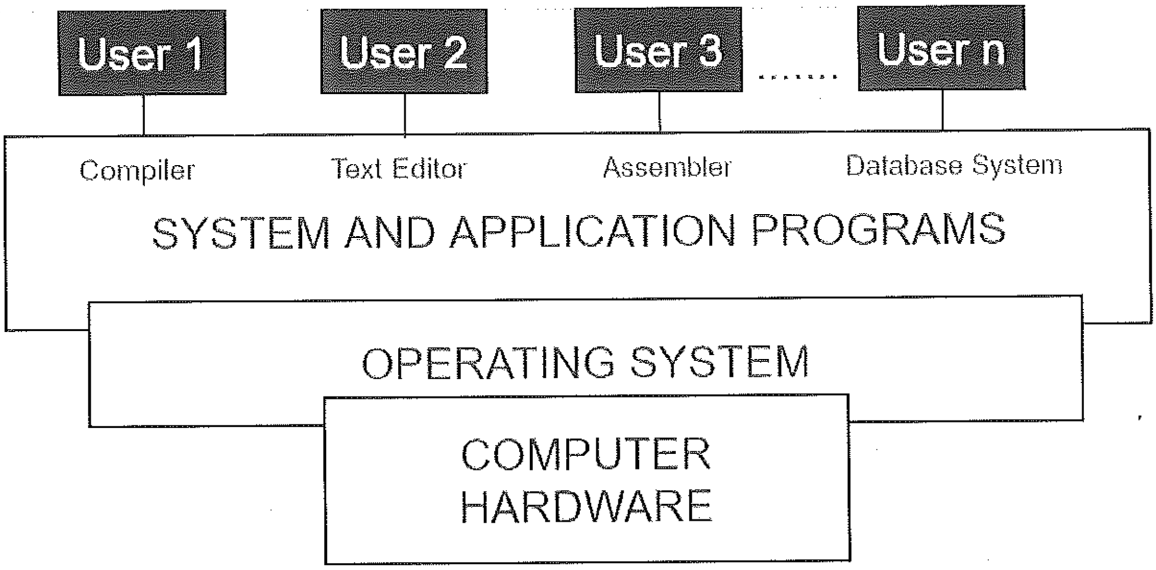


Fig1: Conceptual view of a computer system

Every computer must have an operating system to run other programs. The operating system coordinates the use of the hardware among the various system programs and application programs for various users. It simply provides an environment within which other programs can do useful work.

The operating system is a set of special programs that run on a computer system that allows it to work properly. It performs basic tasks such as recognizing input from the keyboard, keeping track of files and directories on the disk, sending output to the display screen, and controlling peripheral devices.

OS is designed to serve two basic purposes:

i. It controls the allocation and use of the computing System's resources among the various user and tasks.
ii. It provides an interface between the computer hardware and the programmer that simplifies and makes it feasible for coding, creation, debugging of application programs.

The Operating system must support the following tasks. The task are:

1. Provides the facilities to create, modification of programs and data files using an editor.
2. Access to the compiler for translating the user program from high-level language to machine language.
3. Provide a loader program to move the compiled program code to the computer's memory for execution.
4. Provide routines that handle the details of I/O programming.

EXPERIMENT NUMBER: 1

Objective: - Study of hardware and software requirements of different operating systems (UNIX, LINUX, WINDOWS XP, WINDOWS7/8

Content:

Hardware requirements: The most common set of requirements defined by any operating system or software application is the physical computer resources, also known as hardware, A hardware requirements list is often accompanied by a hardware compatibility list (HCL), especially in case of operating systems.

Hardware and Software Minimum Requirements

1. **Windows 10**

   i. Processor: 1 gigahertz (GHz) or faster processor or SoC
   ii. RAM: 1 gigabyte (GB) for 32-bit or 2 GB for 64-bit
   iii. Hard disk space: 16 GB for 32-bit OS or 20 GB for 64-bit OS
   iv. Graphics card: DirectX 9 or later with WDDM 1.0 driver
   v. Display: 800 x 6009 with WDDM driver

2. **WINDOWS XP**

The minimum hardware requirements for Windows XP Home Edition are:

   i. Pentium 233-megahertz (MHz) processor or faster (300 MHz is recommended)
   ii. At least 64 megabytes (MB) of RAM (128 MB is recommended)
   iii. At least 1.5 gigabytes (GB) of available space on the hard disk
   iv. CD-ROM or DVD-ROM drive
   v. Keyboard and a Microsoft Mouse or some other compatible pointing device
   vi. Video adapter and monitor with Super VGA (800 x 600)or higher resolution
   vii. Sound card
   viii. Speakers or headphones

3. **UNIX OS**

   vi. RAM: 1 GB
   vii. Processor: IBM 604e processor with a clock speed of 375 MHz or faster
   viii. Free disk space: /tmp must have 1 GB free disk space. If Tivoli Identity Manager installs WebSphere Application Server, {WAS_HOME} must have 800 MB free disk space and /var must have 300 MB free disk space. Allocate 500 MB for /itim45.

4. **LINUX**

- 32-bit Intel-compatible processor running at 2 GHz or greater
- 512 MB RAM
- Disk space: 2.5 GB for Pipeline Pilot server plus components
- A DVD-ROM drive

Assignment:

Q1. Study the hardware and software requirements of different operating systems.

EXPERIMENT NUMBER: 2

Objective: - Execute various UNIX system calls for

i. Process management
ii. File management
iii. Input/output Systems calls

Content:

The interface between a process and an operating system is provided by system calls. In general, system calls are available as assembly language instructions. They are also included in the manuals used by the assembly level programmers.

Unix System Calls

System calls in Unix are used for file system control, process control, interprocess communication etc. Access to the Unix kernel is only available through these system calls. Generally, system calls are similar to function calls, the only difference is that they remove the control from the user process.

There are around 80 system calls in the Unix interface currently. Details about some of the important ones are given as follows -

System Call	Description
access()	This checks if a calling process has access to the required file
chdir()	The chdir command changes the current directory of the system
chmod()	The mode of a file can be changed using this command
chown()	This changes the ownership of a particular file
kill()	This system call sends kill signal to one or more processes
link()	A new file name is linked to an existing file using link system call.
open()	This opens a file for the reading or writing process
pause()	The pause call suspends a file until a particular signal occurs.
stime()	This system call sets the correct time.
times()	Gets the parent and child process times
alarm()	The alarm system call sets the alarm clock of a process
fork()	A new process is created using this command
chroot()	This changes the root directory of a file.

System Call	Description
exit()	The exit system call is used to exit a process.

```
File Structure          Creating a Channel          creat()
Related Calls                                       open()
                                                    close()
                        Input/Output                read()
                                                    write()
                        Random Access               lseek()
                        Channel Duplication         dup()
                        Aliasing and Removing       link()
                        Files                       unlink()
                        File Status                 stat()
                                                    fstat()
                        Access Control              access()
                                                    chmod()
                                                    chown()
                                                    umask()
                        Device Control              ioctl()
---------------------------------------------------------------------
Process Related         Process Creation and        exec()
Calls                   Termination                 fork()
                                                    wait()
                                                    exit()
                        Process Owner and Group     getuid()
                                                    geteuid()
                                                    getgid()
                                                    getegid()
                        Process Identity            getpid()
                                                    getppid()
                        Process Control             signal()
                                                    kill()
                                                    alarm()
                        Change Working Directory    chdir()
---------------------------------------------------------------------
Interprocess            Pipelines                   pipe()
Communication           Messages                    msgget()
                                                    msgsnd()
                                                    msgrcv()
                                                    msgctl()
                        Semaphores                  semget()
                                                    semop()
                        Shared Memory               shmget()
                                                    shmat()
                                                    shmdt()
---------------------------------------------------------------------
```

```
/* errmsg1.c
    print all system error messages using "perror()"
  */

  #include <stdio.h>

  int main()
  {
    int i;
    extern int errno, sys_nerr;
```

```
  for (i = 0; i < sys_nerr; ++i)
    {
    fprintf(stderr, "%3d",i);
    errno = i;
    perror(" ");
    }
  exit (0);
}
```

```
/* errmsg2.c
  print all system error messages using the global error message table.
*/

#include <stdio.h>

int main()
{
  int i;
  extern int sys_nerr;
  extern char *sys_errlist[];

  fprintf(stderr,"Here are the current %d error messages:\n\n",sys_nerr);
  for (i = 0; i < sys_nerr; ++i)
    fprintf(stderr,"%3d: %s\n", i, sys_errlist[i]);
}
```

```
/* creat.c */

#include <stdio.h>
#include <sys/types.h>      /* defines types used by sys/stat.h */
#include <sys/stat.h>       /* defines S_IREAD & S_IWRITE      */

int main()
{
  int fd;
  fd = creat("datafile.dat", S_IREAD | S_IWRITE);
  if (fd == -1)
    printf("Error in opening datafile.dat\n");
  else
    {
    printf("datafile.dat opened for read/write access\n");
    printf("datafile.dat is currently empty\n");
    }
```

```
  close(fd);
  exit (0);
}
```

The following is a sample of the manifest constants for the mode argument as defined in /usr/include/sys/stat.h:

```
#define S_IRWXU 0000700    /* -rwx------ */
#define S_IREAD 0000400    /* read permission, owner */
#define S_IRUSR S_IREAD
#define S_IWRITE 0000200   /* write permission, owner */
#define S_IWUSR S_IWRITE
#define S_IEXEC 0000100    /* execute/search permission, owner */
#define S_IXUSR S_IEXEC
#define S_IRWXG 0000070    /* ----rwx--- */
#define S_IRGRP 0000040    /* read permission, group */
#define S_IWGRP 0000020    /* write    "       "  */
#define S_IXGRP 0000010    /* execute/search "   "   */
#define S_IRWXO 0000007    /* -------rwx */
#define S_IROTH 0000004    /* read permission, other */
#define S_IWOTH 0000002    /* write    "       "  */
#define S_IXOTH 0000001    /* execute/search "   "   */
```

open()

Next is the open() system call. open() lets you open a file for reading, writing, or reading and writing.

The prototype for the open() system call is:

```
#include <fcntl.h>

int open(file_name, option_flags [, mode])
char *file_name;
int option_flags, mode;
```

where file_name is a pointer to the character string that names the file, option_flags represent the type of channel, and mode defines the file's access permissions if the file is being created.

The allowable option_flags as defined in "/usr/include/fcntl.h" are:

```
#define  O_RDONLY 0      /* Open the file for reading only */
#define  O_WRONLY 1      /* Open the file for writing only */
#define  O_RDWR   2   /* Open the file for both reading and writing*/
#define  O_NDELAY 04     /* Non-blocking I/O */
```

```
#define  O_APPEND 010     /* append (writes guaranteed at the end) */
#define  O_CREAT 00400  /*open with file create (uses third open arg) */
#define  O_TRUNC  01000   /* open with truncation */
#define  O_EXCL   02000   /* exclusive open */
```

Assignment:

Q1. Execute various UNIX system calls for

i. Process management
ii. File management
iii. Input/output Systems calls

EXPERIMENT NUMBER: 3

Objective: -Implement CPU Scheduling Policies:

i. SJF

ii. FCFS

Content:

FCFS CPU SCHEDULING ALGORITHM

For FCFS scheduling algorithm, read the number of processes/jobs in the system, their CPU burst times. The scheduling is performed on the basis of arrival time of the processes irrespective of their other parameters. Each process will be executed according to its arrival time. Calculate the waiting time and turnaround time of each of the processes accordingly.

SJF CPU SCHEDULING ALGORITHM

For SJF scheduling algorithm, read the number of processes/jobs in the system, their CPU burst times. Arrange all the jobs in order with respect to their burst times. There may be two jobs in queue with the same execution time, and then FCFS approach is to be performed. Each process will be executed according to the length of its burst time. Then calculate the waiting time and turnaround time of each of the processes accordingly.

Program:

1. FCFS SCHEDULING

1. Start
2. Declare the array size
3. Read the number of processes to be inserted
4. Read the Burst times of processes
5. calculate the waiting time of each process wt[i+1]=bt[i]+wt[i]
6. calculate the turnaround time of each process tt[i+1]=tt[i]+bt[i+1]
7. Calculate the average waiting time and average turnaround time.
8. Display the values
9. Stop

```
#include<stdio.h>
#include<conio.h>
void main()
{
int i,j,bt[10],n,wt[10],tt[10],w1=0,t1=0;
float aw,at;
clrscr();
printf("enter no. of processes:\n");
scanf("%d",&n);
printf("enter the burst time of processes:");
for(i=0;i<n;i++)
```

```
scanf("%d",&bt[i]);
for(i=0;i<n;i++)
{
wt[0]=0;
tt[0]=bt[0];
wt[i+1]=bt[i]+wt[i];
tt[i+1]=tt[i]+bt[i+1];
w1=w1+wt[i];
t1=t1+tt[i];
}
aw=w1/n;
at=t1/n;
printf("\nbt\t wt\t tt\n");
for(i=0;i<n;i++)
printf("%d\t %d\t %d\n",bt[i],wt[i],tt[i]);
printf("aw=%f\n,at=%f\n",aw,at);
getch();
}
```

INPUT

Enter no of processes
3
enter bursttime
12
8
20

EXPECTED OUTPUT

bt wt tt
12 0 12
8 12 20
20 20 40
aw=10.666670
at=24.00000

2. SJF SCHEDULING

1. Start
2. Declare the array size
3. Read the number of processes to be inserted
4. Read the Burst times of processes
5. sort the Burst times in ascending order and process with shortest burst time is first executed.
6. calculate the waiting time of each process
wt[i+1]=bt[i]+wt[i]
7. calculate the turnaround time of each process
tt[i+1]=tt[i]+bt[i+1]
8. Calculate the average waiting time and average turnaround time.
9. Display the values
10. Stop

```
#include<stdio.h>
#include<conio.h>
void main()
{
int i,j,bt[10],t,n,wt[10],tt[10],w1=0,t1=0;
float aw,at;
clrscr();
printf("enter no. of processes:\n");
scanf("%d",&n);
printf("enter the burst time of processes:");
for(i=0;i<n;i++)
scanf("%d",&bt[i]);
for(i=0;i<n;i++)
{
for(j=i;j<n;j++)
if(bt[i]>bt[j])
{
t=bt[i];
bt[i]=bt[j];
bt[j]=t;
}
}
for(i=0;i<n;i++)
printf("%d",bt[i]);
for(i=0;i<n;i++)
{
wt[0]=0;
tt[0]=bt[0];
wt[i+1]=bt[i]+wt[i];
tt[i+1]=tt[i]+bt[i+1];
w1=w1+wt[i];
t1=t1+tt[i];
}
aw=w1/n;
at=t1/n;
printf("\nbt\t wt\t tt\n");
for(i=0;i<n;i++)
printf("%d\t %d\t %d\n",bt[i],wt[i],tt[i]);
printf("aw=%f\n,at=%f\n",aw,at);
getch();
}
```

INPUT:

enter no of processes
3
enter burst time
12
8

20

OUTPUT:

bt wt tt
12 8 20
8 0 8
20 20 40
aw=9.33
at=22.64

Assignment: Implement CPU Scheduling Policies:

i. SJF
ii. FCFS

EXPERIMENT NUMBER: 4

Objective: -Implement CPU Scheduling Policies:

i. Round robin
ii. Priority

Content:

ROUND ROBIN CPU SCHEDULING ALGORITHM

For round robin scheduling algorithm, read the number of processes/jobs in the system, their CPU burst times, and the size of the time slice. Time slices are assigned to each process in equal portions and in circular order, handling all processes execution. This allows every process to get an equal chance. Calculate the waiting time and turnaround time of each of the processes accordingly.

PRIORITY CPU SCHEDULING ALGORITHM

For priority scheduling algorithm, read the number of processes/jobs in the system, their CPU burst times, and the priorities. Arrange all the jobs in order with respect to their priorities. There may be two jobs in queue with the same priority, and then FCFS approach is to be performed. Each process will be executed according to its priority. Calculate the waiting time and turnaround time of each of the processes accordingly.

Program:

1. *ROUND ROBIN CPU SCHEDULING ALGORITHM*

ALGORITHM

1. Start
2. Declare the array size
3. Read the number of processes to be inserted
4. Read the burst times of the processes
5. Read the Time Quantum
6. if the burst time of a process is greater than time Quantum then subtract time quantum form the burst time
Else
Assign the burst time to time quantum.
7.calculate the average waiting time and turnaround time of the processes.
8. Display the values
9. Stop

PROGRAM:

```
#include<stdio.h>
#include<conio.h>
void main()
{
int st[10],bt[10],wt[10],tat[10],n,tq;
int i,count=0,swt=0,stat=0,temp,sq=0;
```

```
float awt=0.0,atat=0.0;
clrscr();
printf("Enter number of processes:");
scanf("%d",&n);
printf("Enter burst time for sequences:");
for(i=0;i<n;i++)
{
scanf("%d",&bt[i]);
st[i]=bt[i];
}
printf("Enter time quantum:");
scanf("%d",&tq);
while(1)
{
for(i=0,count=0;i<n;i++)
{
temp=tq;
if(st[i]==0)
{
count++;
continue;
}
if(st[i]>tq)
st[i]=st[i]-tq;
else
if(st[i]>=0)
{
temp=st[i];
st[i]=0;
}
sq=sq+temp;
tat[i]=sq;
}
if(n==count)
break;
}
for(i=0;i<n;i++)
{
wt[i]=tat[i]-bt[i];
swt=swt+wt[i];
stat=stat+tat[i];
}
awt=(float)swt/n;
atat=(float)stat/n;
printf("Process_no Burst time Wait time Turn around time");
for(i=0;i<n;i++)
printf("\n%d\t %d\t %d\t %d",i+1,bt[i],wt[i],tat[i]);
printf("\nAvg wait time is %f Avg turn around time is %f",awt,atat);
```

getch();

2. SJF SCHEDULING

ALGORITHM

1. Start
2. Declare the array size
3. Read the number of processes to be inserted
4. Read the Priorities of processes
5. sort the priorities and Burst times in ascending order
5. calculate the waiting time of each process
wt[i+1]=bt[i]+wt[i]
6. calculate the turnaround time of each process
tt[i+1]=tt[i]+bt[i+1]
6. Calculate the average waiting time and average turnaround time.
7. Display the values
8. Stop

PROGRAM:

```
#include<stdio.h>
#include<conio.h>
void main()
{
int i,j,pno[10],prior[10],bt[10],n,wt[10],tt[10],w1=0,t1=0,s;
float aw,at;
clrscr();
printf("enter the number of processes:");
scanf("%d",&n);
for(i=0;i<n;i++)
{
printf("The process %d:\n",i+1);
printf("Enter the burst time of processes:");
scanf("%d",&bt[i]);
printf("Enter the priority of processes %d:",i+1);
scanf("%d",&prior[i]);
pno[i]=i+1;
}
for(i=0;i<n;i++)
{
for(j=0;j<n;j++)
{
if(prior[i]<prior[j])
{
s=prior[i];
prior[i]=prior[j];
prior[j]=s;
s=bt[i];
bt[i]=bt[j];
```

```
bt[j]=s;
s=pno[i];
pno[i]=pno[j];
pno[j]=s;
}
}
}
for(i=0;i<n;i++)
{
wt[0]=0;
tt[0]=bt[0];
wt[i+1]=bt[i]+wt[i];
tt[i+1]=tt[i]+bt[i+1];
w1=w1+wt[i];
t1=t1+tt[i];
aw=w1/n;
at=t1/n;
}
printf(" \n job \t bt \t wt \t tat \t prior\n");
for(i=0;i<n;i++)
printf("%d \t %d \t %d\t %d\t %d\n",pno[i],bt[i],wt[i],tt[i],prior[i]);
printf("aw=%f \t at=%f \n",aw,at);
getch();
        }
```

Assignment:

Implement CPU Scheduling Policies:

i. Round robin
ii. Priority

EXPERIMENT NUMBER: 5

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

Content:

The banker's algorithm is a resource allocation and deadlock avoidance algorithm that tests for safety by simulating the allocation for predetermined maximum possible amounts of all resources, then makes an "s-state" check to test for possible activities, before deciding whether allocation should be allowed to continue.
Banker's algorithm is named so because it is used in banking system to check whether loan can be sanctioned to a person or not. Suppose there are n number of account holders in a bank and the total sum of their money is S. If a person applies for a loan then the bank first subtracts the loan amount from the total money that bank has and if the remaining amount is greater than S then only the loan is sanctioned. It is done because if all the account holders comes to withdraw their money then the bank can easily do it.

Available :

- It is a 1-d array of size **'m'** indicating the number of available resources of each type.
- Available[j] = k means there are **'k'** instances of resource type $\mathbf{R_j}$

Max :

- It is a 2-d array of size **'n*m'** that defines the maximum demand of each process in a system.
- Max[i, j] = k means process $\mathbf{P_i}$ may request at most **'k'** instances of resource type $\mathbf{R_j}$.

Allocation :

- It is a 2-d array of size **'n*m'** that defines the number of resources of each type currently allocated to each process.
- Allocation[i, j] = k means process $\mathbf{P_i}$ is currently allocated **'k'** instances of resource type $\mathbf{R_j}$

Need :

- It is a 2-d array of size **'n*m'** that indicates the remaining resource need of each process.
- Need [i, j] = k means process $\mathbf{P_i}$ currently need **'k'** instances of resource type $\mathbf{R_j}$ for its execution.
- Need [i, j] = Max [i, j] – Allocation [i, j]

Program:

```
#include<stdio.h>
#include<conio.h>
void main()
{
   int n,r,i,j,k,p,u=0,s=0,m;
   int block[10],run[10],active[10],newreq[10];
   int max[10][10],resalloc[10][10],resreq[10][10];
   int totalloc[10],totext[10],simalloc[10];
   //clrscr();
   printf("Enter the no of processes:");
   scanf("%d",&n);
   printf("Enter the no ofresource classes:");
```

```
scanf("%d",&r);
printf("Enter the total existed resource in each class:");
for(k=1; k<=r; k++)
   scanf("%d",&totext[k]);
printf("Enter the allocated resources:");
for(i=1; i<=n; i++)
   for(k=1; k<=r; k++)
      scanf("%d",&resalloc);
printf("Enter the process making the new request:");
scanf("%d",&p);
printf("Enter the requested resource:");
for(k=1; k<=r; k++)
   scanf("%d",&newreq[k]);
printf("Enter the process which are n blocked or running:");
for(i=1; i<=n; i++)
{
   if(i!=p)
   {
      printf("process %d:\n",i+1);
      scanf("%d%d",&block[i],&run[i]);
   }
}
block[p]=0;
run[p]=0;
for(k=1; k<=r; k++)
{

   j=0;
   for(i=1; i<=n; i++)
   {
      totalloc[k]=j+resalloc[i][k];
      j=totalloc[k];
   }
}
for(i=1; i<=n; i++)
{
   if(block[i]==1||run[i]==1)
      active[i]=1;
   else
      active[i]=0;
}
for(k=1; k<=r; k++)
{
   resalloc[p][k]+=newreq[k];
   totalloc[k]+=newreq[k];
}
for(k=1; k<=r; k++)
{
```

```
    if(totext[k]-totalloc[k]<0)
    {
      u=1;
      break;
    }
  }
  if(u==0)
  {
    for(k=1; k<=r; k++)
      simalloc[k]=totalloc[k];
    for(s=1; s<=n; s++)
      for(i=1; i<=n; i++)
      {
        if(active[i]==1)
        {
          j=0;
          for(k=1; k<=r; k++)
          {
            if((totext[k]-simalloc[k])<(max[i][k]-resalloc[i][k]))
            {
              j=1;
              break;
            }
          }
        }
        if(j==0)

        {
          active[i]=0;
          for(k=1; k<=r; k++)
            simalloc[k]=resalloc[i][k];
        }
      }
    m=0;
    for(k=1; k<=r; k++)
      resreq[p][k]=newreq[k];
    printf("Deadlock willn't occur");
  }
  else
  {
    for(k=1; k<=r; k++)
    {
      resalloc[p][k]=newreq[k];
      totalloc[k]=newreq[k];
    }
    printf("Deadlock will occur");
  }
  getch();
```

}

Assignment:

Q1. Write a C program to simulate Bankers algorithm for the purpose of deadlock avoidance.

EXPERIMENT NUMBER: 6

Objective: - Implement file storage allocation technique:

i. Contiguous(using array)
ii. Linked –list(using linked-list)
iii. Indirect allocation (indexing)

Content: The allocation methods define how the files are stored in the disk blocks. There are three main disk space or file allocation methods.

Contiguous Allocation
Linked Allocation
Indexed Allocation
The main idea behind these methods is to provide:

Efficient disk space utilization.
Fast access to the file blocks.

Program:

SEQUENTIAL FILE ALLOCATION

```
#include<stdio.h>
main()
{
int f[50],i,st,j,len,c,k;
clrscr();
for(i=0;i<50;i++)
f[i]=0;
X:
printf("\n Enter the starting block & length of file");
scanf("%d%d",&st,&len);
for(j=st;j<(st+len);j++)
if(f[j]==0)
{
f[j]=1;
printf("\n%d->%d",j,f[j]);
}
else
{
printf("Block already allocated");
break;
}
if(j==(st+len))
printf("\n the file is allocated to disk");
printf("\n if u want to enter more files?(y-1/n-0)");
scanf("%d",&c);
```

```
if(c==1)
goto X;
else
exit();
getch();
}
```

Output:

Enter the starting block & length of file 4 10
4->1
5->1
6->1
7->1
8->1
9->1
10->1
23
11->1
12->1
13->1
The file is allocated to disk
If you want to enter more files? (Y-1/N-0)

LINKED FILE ALLOCATION

```
#include<stdio.h>
main()
{
int f[50],p,i,j,k,a,st,len,n,c;
clrscr();
for(i=0;i<50;i++)
f[i]=0;
printf("Enter how many blocks that are already allocated");
scanf("%d",&p);
printf("\nEnter the blocks no.s that are already allocated");
for(i=0;i<p;i++)
{
scanf("%d",&a);
f[a]=1;
}
X:
printf("Enter the starting index block & length");
scanf("%d%d",&st,&len);
k=len;
for(j=st;j<(k+st);j++)
{
if(f[j]==0)
{
f[j]=1;
```

```
printf("\n%d->%d",j,f[j]);
}
else
{
printf("\n %d->file is already allocated",j);
k++;
}
}
printf("\n If u want to enter one more file? (yes-1/no-0)");
scanf("%d",&c);
if(c==1)
goto X;
else
exit();
getch( );}
```

INDEXED ALLOCATION TECHNIQUE

```
#include<stdio.h>
int f[50],i,k,j,inde[50],n,c,count=0,p;
main()
{
clrscr();
for(i=0;i<50;i++)
f[i]=0;
x:
printf("enter index block\t");
scanf("%d",&p);
if(f[p]==0)
{
f[p]=1;
printf("enter no of files on index\t");
scanf("%d",&n);
}
else
{
printf("Block already allocated\n");
goto x;
}
for(i=0;i<n;i++)
scanf("%d",&inde[i]);
for(i=0;i<n;i++)
if(f[inde[i]]==1)
{
printf("Block already allocated");
goto x;
```

```
}
for(j=0;j<n;j++)
f[inde[j]]=1;
printf("\n allocated");
printf("\n file indexed");
for(k=0;k<n;k++)
printf("\n %d->%d:%d",p,inde[k],f[inde[k]]);
printf(" Enter 1 to enter more files and 0 to exit\t");
scanf("%d",&c);
if(c==1)
goto x;
else
exit();
getch();
```

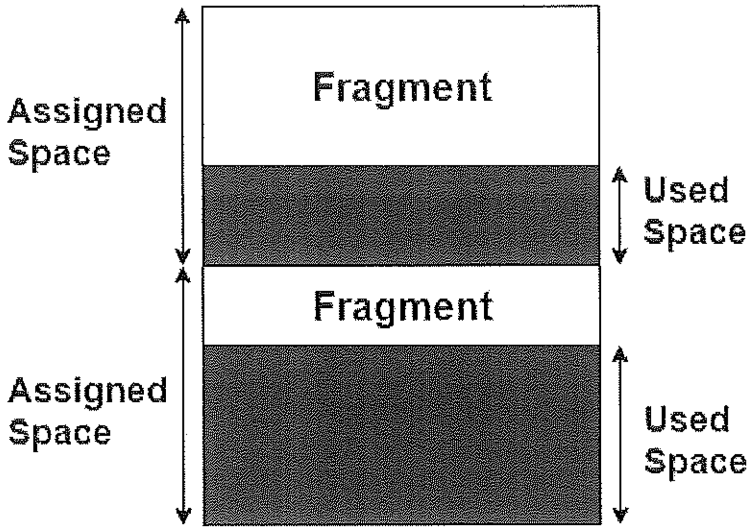
Assignment:

EXPERIMENT NUMBER: 7

Objective: - Calculation of external and internal fragmentation.

Content: There are two types of fragmentation in OS which are given as: Internal fragmentation, and External fragmentation.

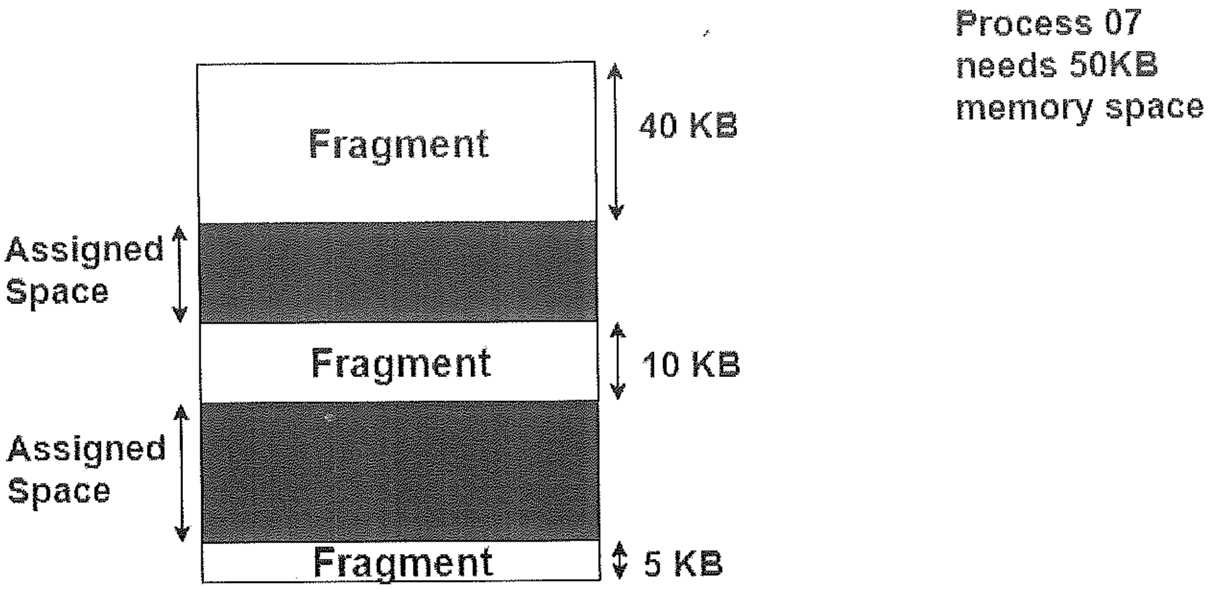
Internal Fragmentation:
Internal fragmentation happens when the memory is split into mounted sized blocks. Whenever a method request for the memory, the mounted sized block is allotted to the method. just in case the memory allotted to the method is somewhat larger than the memory requested, then the distinction between allotted and requested memory is that the Internal fragmentation.



Internal Fragmentation

The above diagram clearly shows the internal fragmentation because the difference between memory allocated and required space or memory is called Internal fragmentation.

External Fragmentation:
External fragmentation happens when there's a sufficient quantity of area within the memory to satisfy the memory request of a method. however the process's memory request cannot be fulfilled because the memory offered is during a non-contiguous manner. Either you apply first-fit or best-fit memory allocation strategy it'll cause external fragmentation.



In above diagram, we can see that, there is enough space (55 KB) to run a process-07 (required 50 KB) but the memory (fragment) is not contiguous. Here, we use compaction, paging or segmentation to use the free space to run a process.

Difference between Internal fragmentation and External fragmentation:-

S.NO	Internal fragmentation	External fragmentation
1.	In internal fragmentation fixed-sized memory, blocks square measure appointed to process.	In external fragmentation, variable-sized memory blocks square measure appointed to method.
2.	Internal fragmentation happens when the method or process is larger than the memory.	External fragmentation happens when the method or process is removed.
3.	The solution of internal fragmentation is best-fit block.	Solution of external fragmentation is compaction, paging and segmentation.
4.	Internal fragmentation occurs when memory is divided into fixed sized partitions.	External fragmentation occurs when memory is divided into variable size partitions based on the size of processes.
5.	The difference between memory allocated and required space or memory is called Internal fragmentation.	The unused spaces formed between non-contiguous memory fragments are too small to serve a new process, is called External fragmentation .

Assignment:

Q1. Calculation of external and internal fragmentation.

EXPERIMENT NUMBER: 8

Objective: - Write a C program to simulate the following contiguous memory allocation techniques a) Worst-fit b) Best-fit c) First-fit

Content: One of the simplest methods for memory allocation is to divide memory into several fixed-sized partitions. Each partition may contain exactly one process. In this multiple-partition method, when a partition is free, a process is selected from the input queue and is loaded into the free partition. When the process terminates, the partition becomes available for another process. The operating system keeps a table indicating which parts of memory are available and which are occupied. Finally, when a process arrives and needs memory, a memory section large enough for this process is provided. When it is time to load or swap a process into main memory, and if there is more than one free block of memory of sufficient size, then the operating system must decide which free block to allocate. Best-fit strategy chooses the block that is closest in size to the request. First-fit chooses the first available block that is large enough. Worst-fit chooses the largest available block.

Program:

1. First Fit algorithm in Memory Management

Implementation:
1- Input memory blocks with size and processes with size.
2- Initialize all memory blocks as free.
3- Start by picking each process and check if it can
  be assigned to current block.
4- If size-of-process <= size-of-block if yes then
  assign and check for next process.
5- If not then keep checking the further blocks.

```
// C++ implementation of First - Fit algorithm
#include<bits/stdc++.h>
using namespace std;

// Function to allocate memory to
// blocks as per First fit algorithm
void firstFit(int blockSize[], int m,
                        int processSize[], int n)
{
        // Stores block id of the
        // block allocated to a process
        int allocation[n];

        // Initially no block is assigned to any process
        memset(allocation, -1, sizeof(allocation));

        // pick each process and find suitable blocks
        // according to its size ad assign to it
```

```
        for (int i = 0; i < n; i++)
        {
         for (int j = 0; j < m; j++)
         {
                if (blockSize[j] >= processSize[i])
                {
                        // allocate block j to p[i] process
                        allocation[i] = j;

                        // Reduce available memory in this block.
                        blockSize[j] -= processSize[i];

                        break;
                }
         }
        }

        cout << "\nProcess No.\tProcess Size\tBlock no.\n";
        for (int i = 0; i < n; i++)
        {
         cout << " " << i+1 << "\t\t"
                << processSize[i] << "\t\t";
         if (allocation[i] != -1)
                cout << allocation[i] + 1;
         else
                cout << "Not Allocated";
         cout << endl;
        }
}

// Driver code
int main()
{
        int blockSize[] = {100, 500, 200, 300, 600};
        int processSize[] = {212, 417, 112, 426};
        int m = sizeof(blockSize) / sizeof(blockSize[0]);
        int n = sizeof(processSize) / sizeof(processSize[0]);

        firstFit(blockSize, m, processSize, n);

        return 0 ;
}
```

2. Best Fit algorithm in Memory Management

Implementation:
1- Input memory blocks and processes with sizes.
2- Initialize all memory blocks as free.
3- Start by picking each process and find the minimum block size that can be assigned to current process i.e., find min(bockSize[1], blockSize[2],.....blockSize[n]) > processSize[current], if found then assign it to the current process.
5- If not then leave that process and keep checking the further processes.

```
// C++ implementation of Best - Fit algorithm
#include<bits/stdc++.h>
using namespace std;

// Function to allocate memory to blocks as per Best fit
// algorithm
void bestFit(int blockSize[], int m, int processSize[], int n)
{
		// Stores block id of the block allocated to a
		// process
		int allocation[n];

		// Initially no block is assigned to any process
		memset(allocation, -1, sizeof(allocation));

		// pick each process and find suitable blocks
		// according to its size ad assign to it
		for (int i=0; i<n; i++)
		{
		 // Find the best fit block for current process
		 int bestIdx = -1;
		 for (int j=0; j<m; j++)
		 {
			if (blockSize[j] >= processSize[i])
			{
				if (bestIdx == -1)
					bestIdx = j;
				else if (blockSize[bestIdx] > blockSize[j])
					bestIdx = j;
			}
		 }
```

```
            // If we could find a block for current process
            if (bestIdx != -1)
            {
                    // allocate block j to p[i] process
                    allocation[i] = bestIdx;

                    // Reduce available memory in this block.
                    blockSize[bestIdx] -= processSize[i];
            }
            }

        cout << "\nProcess No.\tProcess Size\tBlock no.\n";
        for (int i = 0; i < n; i++)
        {
         cout << " " << i+1 << "\t\t" << processSize[i] << "\t\t";
         if (allocation[i] != -1)
                 cout << allocation[i] + 1;
         else
                 cout << "Not Allocated";
         cout << endl;
        }
}

// Driver code
int main()
{
        int blockSize[] = {100, 500, 200, 300, 600};
        int processSize[] = {212, 417, 112, 426};
        int m = sizeof(blockSize)/sizeof(blockSize[0]);
        int n = sizeof(processSize)/sizeof(processSize[0]);

        bestFit(blockSize, m, processSize, n);

        return 0 ;
}
```

3. Worst Fit algorithm in Memory Management

Implementation:
1- Input memory blocks and processes with sizes.
2- Initialize all memory blocks as free.
3- Start by picking each process and find the maximum block size that can be assigned to current process i.e., find max(bockSize[1], blockSize[2],.....blockSize[n]) >

processSize[current], if found then assign
it to the current process.
5- If not then leave that process and keep checking
the further processes.

```
// C++ implementation of worst - Fit algorithm
#include<bits/stdc++.h>
using namespace std;

// Function to allocate memory to blocks as per worst fit
// algorithm
void worstFit(int blockSize[], int m, int processSize[],
                                                        int n)
{
        // Stores block id of the block allocated to a
        // process
        int allocation[n];

        // Initially no block is assigned to any process
        memset(allocation, -1, sizeof(allocation));

        // pick each process and find suitable blocks
        // according to its size ad assign to it
        for (int i=0; i<n; i++)
        {
         // Find the best fit block for current process
         int wstIdx = -1;
         for (int j=0; j<m; j++)
         {
                if (blockSize[j] >= processSize[i])
                {
                        if (wstIdx == -1)
                                wstIdx = j;
                        else if (blockSize[wstIdx] < blockSize[j])
                                wstIdx = j;
                }
         }

         // If we could find a block for current process
         if (wstIdx != -1)
         {
                // allocate block j to p[i] process
                allocation[i] = wstIdx;

                // Reduce available memory in this block.
                blockSize[wstIdx] -= processSize[i];
         }
```

```
        }

        cout << "\nProcess No.\tProcess Size\tBlock no.\n";
        for (int i = 0; i < n; i++)
        {
         cout << " " << i+1 << "\t\t" << processSize[i] << "\t\t";
         if (allocation[i] != -1)
                cout << allocation[i] + 1;
         else
                cout << "Not Allocated";
         cout << endl;
        }
}

// Driver code
int main()
{
        int blockSize[] = {100, 500, 200, 300, 600};
        int processSize[] = {212, 417, 112, 426};
        int m = sizeof(blockSize)/sizeof(blockSize[0]);
        int n = sizeof(processSize)/sizeof(processSize[0]);

        worstFit(blockSize, m, processSize, n);

        return 0 ;
}
```

Assignment:

Q1. Implementation of contiguous allocation techniques:

i. Worst-Fit
ii. Best- Fit
iii. First- Fit

EXPERIMENT NUMBER: 9

Objective: - Implement the solution for Bounded Buffer (producer-consumer) problem using inter process communication techniques-Semaphores.

Content: Producer consumer problem is a classical synchronization problem. We can solve this problem by using semaphores.

A semaphore S is an integer variable that can be accessed only through two standard operations : wait() and signal().
The wait() operation reduces the value of semaphore by 1 and the signal() operation increases its value by 1.

```
wait(S){
while(S<=0);   // busy waiting
S--;
}

signal(S){
S++;
}
```

Semaphores are of two types:

Binary Semaphore – This is similar to mutex lock but not the same thing. It can have only two values – 0 and 1. Its value is initialized to 1. It is used to implement the solution of critical section problem with multiple processes.
Counting Semaphore – Its value can range over an unrestricted domain. It is used to control access to a resource that has multiple instances.

Program:

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

int mutex=1,full=0,empty=3,x=0;

int main()
{
        int n;
        void producer();
        void consumer();
        int wait(int);
        int signal(int);
        printf("\n1.Producer\n2.Consumer\n3.Exit");
        while(1)
        {
                printf("\nEnter your choice:");
                scanf("%d",&n);
                switch(n)
                {
                        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:
                                exit(0);
                                break;
            }
        }

        return 0;
}

int wait(int s)
{
        return (--s);
}

int signal(int s)
{
        return(++s);
}

void producer()
{
        mutex=wait(mutex);
        full=signal(full);
        empty=wait(empty);
        x++;
        printf("\nProducer produces the item %d",x);
        mutex=signal(mutex);
}

void consumer()
{
        mutex=wait(mutex);
        full=wait(full);
        empty=signal(empty);
        printf("\nConsumer consumes item %d",x);
        x--;
        mutex=signal(mutex);
}
```

Assignment:

Q1. - Implement the solution for Bounded Buffer (producer-consumer) problem using inter process communication techniques-Semaphores.

EXPERIMENT NUMBER: 10

Objective: - Implementation of resource allocation graph RAG

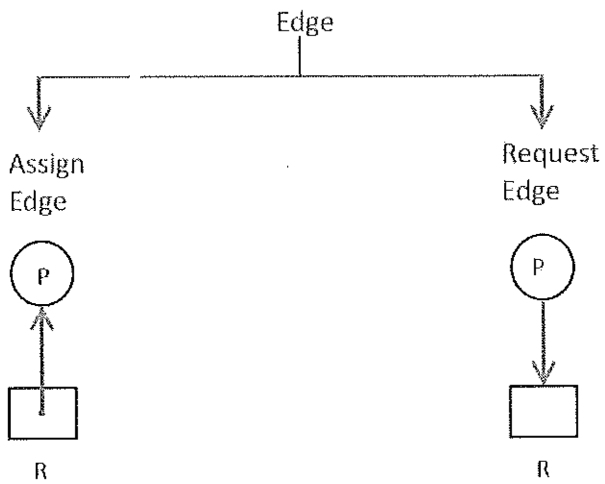
Content:
The resource allocation graph is the pictorial representation of the state of a system. As its name suggests, the resource allocation graph is the complete information about all the processes which are holding some resources or waiting for some resources.
It also contains the information about all the instances of all the resources whether they are available or being used by the processes.

o RAG also contains vertices and edges. In RAG vertices are two type –
1. Process vertex – Every process will be represented as a process vertex.Generally, the process will be represented with a circle.
2. Resource vertex – Every resource will be represented as a resource vertex. It is also two type –

- **Single instance type resource** – It represents as a box, inside the box, there will be one dot.So the number of dots indicate how many instances are present of each resource type.
- **Multi-resource instance type resource** – It also represents as a box, inside the box, there will be many dots present.

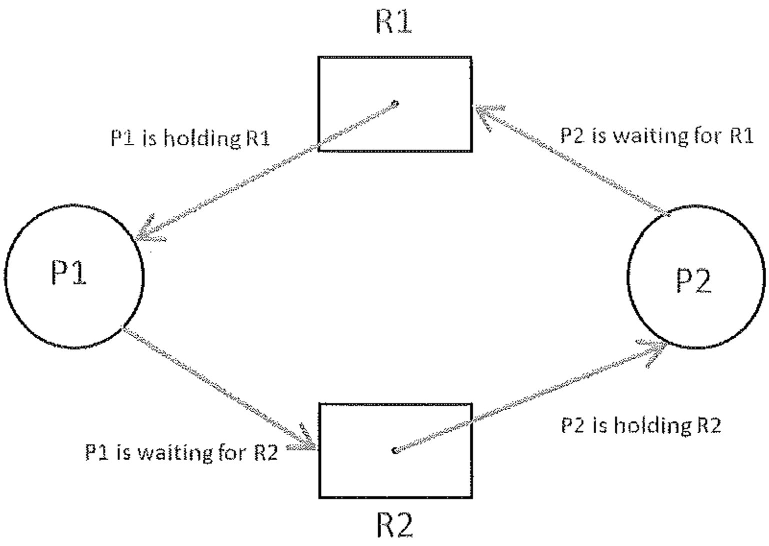
Now coming to the edges of RAG.There are two types of edges in RAG –

1. Assign Edge – If you already assign a resource to a process then it is called Assign edge.
2. Request Edge – It means in future the process might want some resource to complete the execution, that is called request edge.



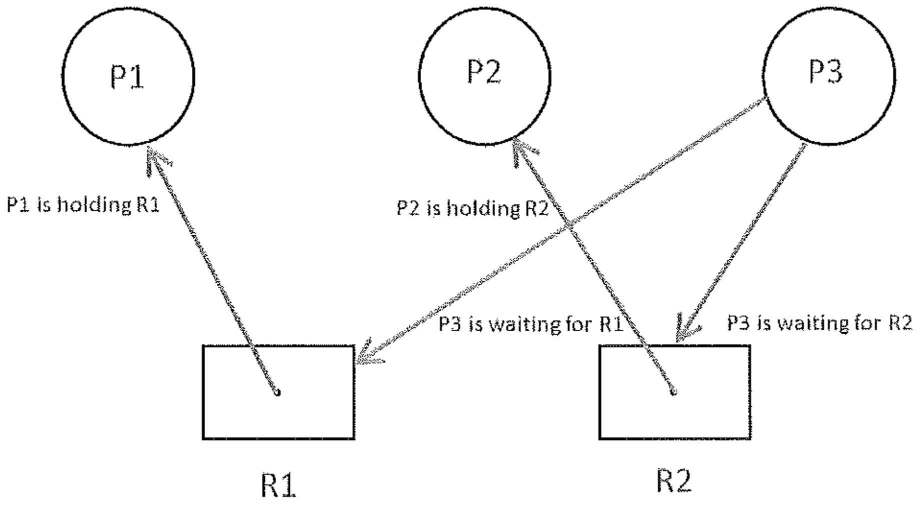
So, if a process is using a resource, an arrow is drawn from the resource node to the process node. If a process is requesting a resource, an arrow is drawn from the process node to the resource node.

Example 1 (Single instances RAG) –



SINGLE INSTANCE RESOURCE TYPE WITH DEADLOCK

If there is a cycle in the Resource Allocation Graph and each resource in the cycle provides only one instance, then the processes will be in deadlock. For example, if process P1 holds resource R1, process P2 holds resource R2 and process P1 is waiting for R2 and process P2 is waiting for R1, then process P1 and process P2 will be in deadlock.

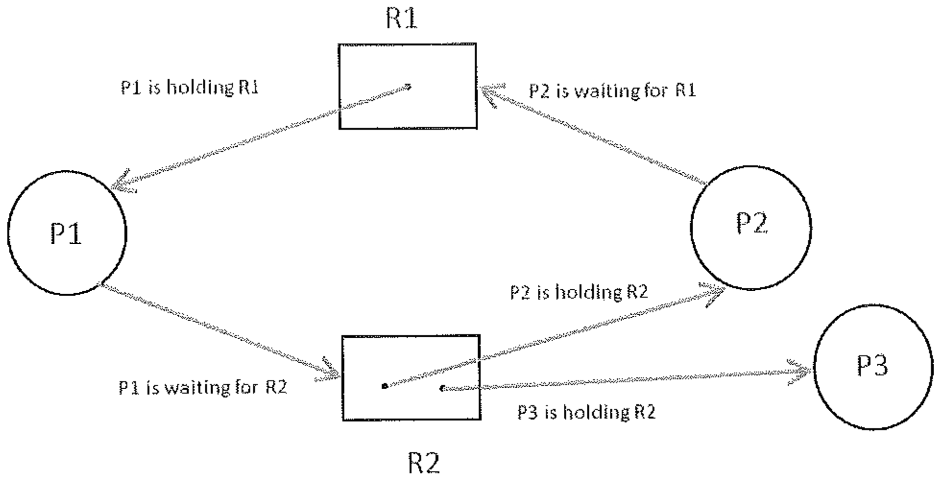


SINGLE INSTANCE RESOURCE TYPE WITHOUT DEADLOCK

Here's another example,that shows Processes P1 and P2 acquiring resources R1 and R2 while process P3 is waiting to acquire both resources. In this example, there is no deadlock because there is no circular

dependency.
So cycle in single-instance resource type is the sufficient condition for deadlock.

Example 2 (Multi-instances RAG) –



MULTI INSTANCES WITHOUT DEADLOCK

From the above example, it is not possible to say the RAG is in a safe state or in an unsafe state.So to see the state of this RAG, let's construct the allocation matrix and request

Process	Allocation		Request	
	Resource		Resource	
	R1	R2	R1	R2
P1	1	0	0	1
P2	0	1	1	0
P3	0	1	0	0

matrix.

- The total number of processes are three; P1, P2 & P3 and the total number of resources are two; R1 & R2.

Allocation matrix –

- For constructing the allocation matrix, just go to the resources and see to which process it is allocated.
- R1 is allocated to P1, therefore write 1 in allocation matrix and similarly, R2 is allocated to P2 as well as P3 and for the remaining element just write 0.

Request matrix –

- In order to find out the request matrix, you have to go to the process and see the outgoing edges.
- P1 is requesting resource R2, so write 1 in the matrix and similarly, P2 requesting R1 and for the remaining element write 0.

So now available resource is = (0, 0).

Checking deadlock (safe or not) –

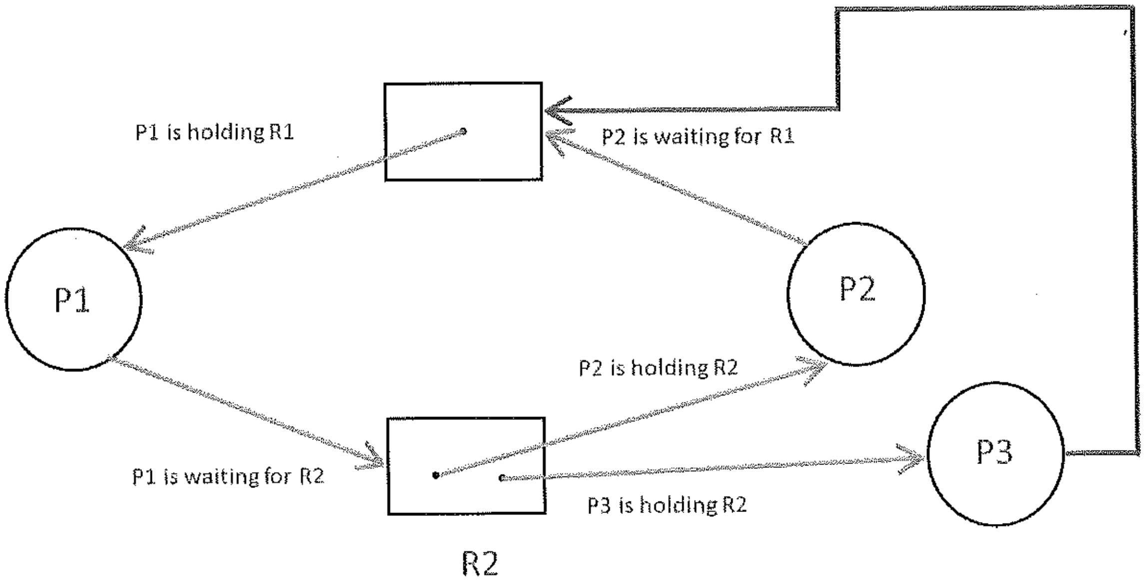
Available = 0 0 (As P3 does not require any extra resource to complete the execution and after
P3 0 1 completion P3 release its own resource)

New Available = 0 1 (As using new available resource we can satisfy the requirment of process P1
P1 1 0 and P1 also release its prevous resource)

New Available = 1 1 (Now easily we can satisfy the requirement of process P2)
P2 0 1

New Available = 1 2

So, there is no deadlock in this RAG.Even though there is a cycle, still there is no deadlock.Therefore in multi-instance resource cycle is not sufficient condition for deadlock.



MULTI INSTANCES WITH DEADLOCK

Above example is the same as the previous example except that, the process P3 requesting for resource R1.
So the table becomes as shown in below.

Process	Allocation		Request	
	Resource		Resource	
	R1	R2	R1	R2
P1	1	0	0	1
P2	0	1	1	0
P3	0	1	1	0

So,the Available resource is = (0, 0), but requirement are (0, 1), (1, 0) and (1, 0).So you can't fulfill any one requirement.Therefore, it is in deadlock.
Therefore, every cycle in a multi-instance resource type graph is not a deadlock, if there has to be a deadlock, there has to be a cycle.So, in case of RAG with multi-instance resource type, the cycle is a necessary condition for deadlock, but not sufficient.

Program:

```
// C program to demonstrate waitpid()
#include<stdio.h>
#include<stdlib.h>
#include<sys/wait.h>
#include<unistd.h>

void waitexample()
{
        int i, stat;
        pid_t pid[5];
        for (i=0; i<5; i++)
        {
         if ((pid[i] = fork()) == 0)
         {
                sleep(1);
                exit(100 + i);
```

```
        }
    }

    // Using waitpid() and printing exit status
    // of children.
    for (i=0; i<5; i++)
    {
     pid_t cpid = waitpid(pid[i], &stat, 0);
     if (WIFEXITED(stat))
            printf("Child %d terminated with status: %d\n",
                    cpid, WEXITSTATUS(stat));
    }
}

// Driver code
int main()
{
    waitexample();
    return 0;
}
```

Assignment:

Q1. Implementation of resource allocation graph RAG.