SURNAME		NAME		Group
ID		Signature		

- **Keep the exam sheets stapled.**
- **Write your answer inside the reserved space.**
- **Use clear and understandable writing. Answer briefly and precisely.**
- **The exam has 9 questions, everyone has its score specified.**

1. A computer manages its 1MB of logical memory space by paging with 512-byte pages. The memory map of a given process reserves space for three contiguous regions: one for 1100 instructions of 4 byte each instruction (all contiguous), another for 130 global variables of 8 byte each variable (also contiguous) and a third region for the stack. The system dynamically allocates the minimum number of pages for the stack

(1,2 points = 0,3 + 0,3 + 0,3 + 0,3)

1

a) How many bits are reserved for the page id in the logical address ?

Page size is 2^9 bytes, they remain 20 – 9 = 11 bits for page id

b) How many pages are needed to store the instructions of this process? And how many for its global variables? ?

Instructions require 1100 x 4 = 4400 Bytes, they are allocated into 4400 / 512 = 9 pages
Global variables occupy 130 x 8 = 1040 Bytes; 1040 / 512 = 3 pages

c) By the time the stack has grown up to 1,800 bytes, how many entries in the process page table will be valid?

The stack requires 4 pages, so the table will have 4 + 9 + 3 = 16 valid entries

d) Compute the internal fragmentation in bytes at the time instant considered on item **c)**

If there are 16 valid pages, with 8192 bytes of whole capacity, and the process requires:
4400 + 1040 + 1800 = 7240 bytes, internal fragmentation will be 8192 - 7240 = 952 bytes

2. Let consider a timesharing system with a short-term scheduler with a single ready queue. At time t = 0 processes A, B and C arrive in this order to the ready queue. All three processes are CPU bounded with the same execution profile: :

1000 CPU	10 E/S	1000 CPU	10 E/S	10 CPU

Obtain with explanation the turnaround time and the waiting time for every process (A, B and C) on the following cases:

(1,2 points = 0,5 + 0,5 + 0,2)

2

a) FCFS scheduling

First come first served. First process A will occupy the CPU and it won't leave it until its CPU burst be finished. I/O bursts a very small compared to the CPU ones for every process. A time sharing system overlaps I/O bursts from one process with CPU bursts of another. So CPU utilization will be:

1000A+1000B+1000C+1000A+1000B+1000C+10A+10B+10C → 100%

Tr(A)=6010, Tr(B)=6020, Tr(C)=6030

Tw(A)=6010-2030=3980, Tw(B)=6020-2030=3990, Tw(C)=6030-2030=4000.

Ready - BC -CA(-10)-AB(-10)-BC(-10)-CA(-10)-AB(-10)- B - C -----

CPU - 1000A- 1000B - 1000C - 1000A - 1000B - 1000C - 10A- 10B- 10C

I/o ->-------10A-----10B-----10C-----10A-----10B-----10C ---------

Turnaround time			Waiting time		
A=	B=	C=	A=	B=	C=

b) RR with q = 10 ut

Processes occupy the CPU rounding every 10ut. First A occupies the CPU for 10ut, the B for another 10ut and then C and so on. The time quantum q is the same as the I/O bursts length (10ut) that overlap with the CPU occupation of another process. On the CPU we will have:

(10A+10B+10C)*100 times+(10A+10B+10C)*100 times+10A+10B+10C

CPU utilization is 100%.

Tr(A)=6010, Tr(B)=6020, Tr(C)=6030

Tw(A)=6010-2030=3980, Tw(B)=6020-2030=3990, Tw(C)=6030-2030=4000.

Ready - A(-1010)B(-1010)C(-1000)-A(-1010)B(-1010)C(-1010)- B - C ---

CPU -(10A + 10B + 10C)* 100 -(10A + 10B+ 10C)*100 -10A-10B-10C

I/O ->--------------10A-10B-----10C--------------10A-10B-10C ------

Turnaround time			Waiting time		
A=	B=	C=	A=	B=	C=

c) Taking into consideration the cost for context switching, explain what algorithm FCFS or RR gives better performance in this situation.

With FCFS there are about 9 context switches, while with RR there are about 603. Considering the required number of context switches we can guess that FCFS will have better performance. Context switch takes time (overhead) because the OS has to take the CPU to manage them. This overhead increases the turnaround time and the waiting time for every process

3. Given the following code that has generated the executable file named "Example1":

```
1  /*** Example1.c ***/
2  #include "all_required_headers.h"
3  #define N 2
4
5  main() {
6    int i=0, j=0;
7    pid_t pid;
8    while (i<N) {
9      pid = fork();
10     if (pid ==0) {
11       for (j=0; j<i ; j++) {
12          fork();
13          printf("Child i=%d, j=%d \n", i, j);
14          exit(0);
15       }
16     } else {
17       printf("Parent i=%d, j=%d \n", i, j);
18       while (wait(NULL) != -1);
19     }
20     i++;
21   }
22   exit(0);
23 }
```

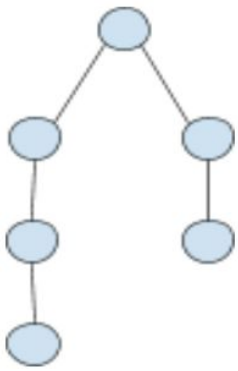
Answer with enough explanation the following items:

(1,2 points = 0,6 + 0,6)

3

a) The number of processes that are generated and draw their parentship graph.

6 processes are generated with the following parentship



b) Write the messages that are printed on the screen when executing "Example1".

```
Parent i=0,j=0
Parent i=1,j=0
Parent i=1,j=0
Child i=1,j=0
Child i=1,j=0
Child i=1,j=0
Child i=1,j=0
```

4. The following program `threads.c` includes function `rever()` that reverses the string passed as argument:

```
 1 #include "all_required_headers.h"
 2 #define ARG_MAX 20
 3 int done=0;
 4
 5 void *rever( void *ptr ){
 6  int i;
 7  char temp;
 8  char *pfirst= (char*) ptr;
 9  char *plast= pfirst+strlen(pfirst)-1;
10  while (plast > pfirst){
11    temp= *pfirst;
12    *pfirst= *plast;  *plast= temp;
13    pfirst++; plast--;
14  }
15  done++;
16 }
```

```
17 int main(int argc, char* argv[]){
18  int i;
19  pthread_t thr[ARG_MAX];
20  pthread_attr_t atrib;
21  pthread_attr_init(&atrib);
22
23  for(i=1;i<argc;i++)
24    pthread_create(&thr[i],&atrib,
                rever,(void *)argv[i]);
25
26  for(i=argc-1;i>0;i--){
27    pthread_join(thr[i],NULL);
28    printf("%s ",argv[i]);
29  }
30 }
```

Answer the following items considering that the program is compiled and executed as follows: :

```
gcc threads.c -o threads -lpthread
./threads once upon a time
```

(1,0 points = 0,25 + 0,25 + 0,25 + 0,25)

4

a) What is the maximum number of threads that execute concurrently?

5 threads, one thread per every one of the 4 parameters, and the main thread.

b) What is shown in the standard output after the program execution?

"emit a nopu ecno " every one of the 4 threads inverts concurrently one of the parameters. The main thread waits correctly every parameter inversion and prints them in reverse order from the last one to the first one

c) How could affect the output generated by the program if removing line 27?

The main thread would print the parameters without waiting for the complete inversion. The parameter order would be inverted, but some of them maybe not

d) If in the original program line 27 is removed and the following line is inserted into line 25:

```
while (done < argc-1);
```

Would it work properly, resulting in the same output than the original program?

Maybe it won't work, because a race condition appears with shared variable `done`, due to the change (increment) done by the threads without any synchronization. This implies that the final value of this variable won't end up with the number of "rever" threads ended, as intended

5. It is wanted to manage the entrance to an amusement park limited to 5,000 people. To do this a process implements the park entering and leaving tasks by two threads that execute functions "func_enter" and "func_leave" respectively. These two functions have to monitor that no more entries will happen when the park capacity is reached and no outputs are accounted when there is nobody inside the park. In addition we want to know at every moment the actual number of visitor inside the park, that will be stored on variable "visitors" that the threads will modify properly.

To solve the synchronization problems that arise three semaphores are used:

- mutex : controls critical section access
- vacants : indicates the number of available entrances
- people : indicates the number of visitors inside the park

a) Complete the code for the main program initializing the defined semaphores.

b) Complete the code for functions "func_enter" and "func_leave", performing the required operations on the appropriate semaphores.

(1,0 points = 0,5 + 0,5)

5

a)

```
#include <semaphore.h>
#define N 5000
int visitors;
sem_t mutex, vacants, people;
pthread_t enter, leave;
void main () {
  // Semaphore initialization
  sem_init(&mutex, 0, 1);
  sem_init(&vacants, 0, N);
  sem_init(&people, 0, 0);
  //
  pthread_create(&enter, NULL , func_enter, NULL);
  pthread_create(&leave, NULL , func_leave, NULL);
  ...
}
```

b)

```
void *func_enter(void *p) {
  while (1) {
    sem_wait(&vacants)
    sem_wait(&mutex)
    visitors = visitors + 1;
    sem_post(&mutex)
    sem_post(&people)
  }
}
```

```
void *fun_leave(void *p) {
  while (1) {
    sem_wait(&people)
    sem_wait(&mutex)
    visitors = visitors - 1;
    sem_post(&mutex)
    sem_post(&vacants)
  }
}
```

6. Given a system with **virtual memory** by **demand paging** and **GLOBAL LRU replacement** algorithm, pages are 4KB, main memory is 40 KB (10 frames) and the maximum size of a process is 16KB (4 pages). The LRU algorithm is implemented using counters, annotating the time instant when the page is referenced. The allocation of frames in main memory is in ascending order. At t = 10, there are 3 processes with the following content on their page tables:

Page table for process A			
Page	**Frame**	**Counter**	**Val. bit**
0	2	4	v
1	5	1	v
2			i
3	1	5	v

Page table for process B			
Page	**Frame**	**Counter**	**Val. bit**
0	0	2	v
1	3	3	v
2			i
3			i

Page table for process C			
Page.	**Frame**	**Counter**	**Val. bit**
0	4	10	v
1	8	7	v
2	9	8	v
3			i

Consider the state of the system at t = 10 and answer the following questions:

a) Indicate the process and page number occupying every main memory frame. Fill in the table with the following format: A0 corresponds to page 0 from process A .

b) From t = 10, the following logical addresses are referenced (**addresses in hexadecimal**): (A, 2F2C), (C, 3001), (A, 11C1), (B, 3152). Fill the content of main memory and page tables at the end of the reference sequence.

(1,2 points = 0,6 + 0,6)

6

(TABLE item a))	
Frame	
0	**B0**
1	**A3**
2	**A0**
3	**B1**
4	**C0**
5	**A1**
6	**--**
7	**--**
8	**C1**
9	**C2**

(TABLE item b))	
Frame	
0	**B3**
1	**A3**
2	**A0**
3	**B1**
4	**C0**
5	**A1**
6	**A2**
7	**C3**
8	**C1**
9	**C2**

PAGE TABLES FOR PROCESSESS A, B y C (item b))

Page table for process A			
Page	**Frame**	**Count**	**Val. bit**
0	2	4	v
1	5	**13**	v
2	**6**	**11**	**v**
3	1	5	v

Page table for process A			
Page	**Frame**	**Count**	**Val. bit**
0			**i**
1	3	3	v
2			i
3	**0**	**14**	**v**

Page table for process A			
Page	**Frame**	**Count**	**Val. bit**
0	4	10	v
1	8	7	v
2	9	8	v
3	**7**	**12**	**v**

7. Assume the following C code, that creates 3 processes that communicate using 3 pipes, executes without errors. Answer to the following sections with enough explanation: :

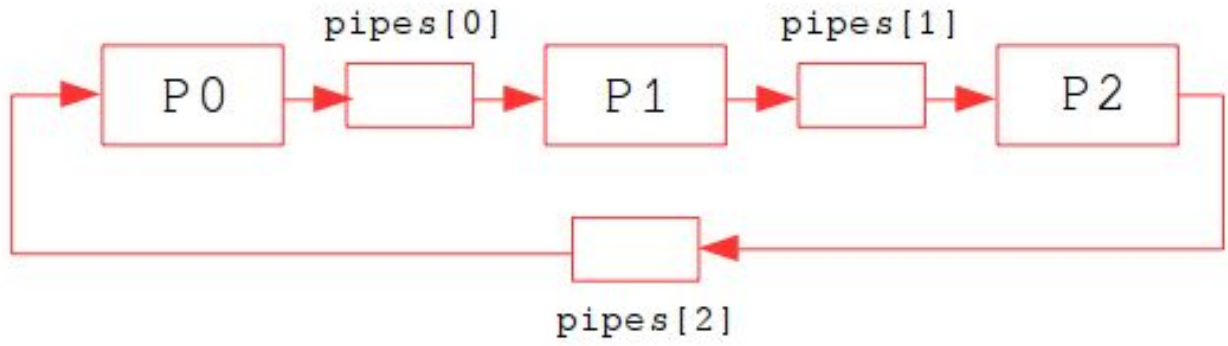
```
   /*** pipes.c   ***/
 1 #include "all_required_headers.h"
 2 #define nproc 3
 3 #define nt 2
 4
 5 int main(int argc,char* argv[]) {
 6   int pipes[nproc][2];
 7   int i, j, pid, i_1;
 8
 9   for (i=0; i<nproc; i++)
10 pipe(pipes[i]);
11   for (i=0; i<nproc; i++) {
12     pid = fork();
13     if (pid == 0) {
14      dup2(pipes[i][1],STDOUT_FILENO);
15      i_1 = i_previous(i, nproc);
16      dup2(pipes[i_1][0],STDIN_FILENO);
17      for (j=0; j<nproc; j++) {
18        close(pipes[j][0]);
19        close(pipes[j][1]);
20       }
21      comp_and_com(i, nt);
22      exit(0);
23     }
24   }
25   for (i=0; i<nproc; i++) {
26     close(pipes[i][0]);
27     close(pipes[i][1]);
28    }
29   while (wait(NULL) != -1);
30   exit(0);
   }
```

```
31 int comp_and_com(id, nturns) {
32   int v, n;
33   n = 0;
34   while (n < nturns) {
35     if (id == 0 && n == 0) {
36       v = 0;
37       n++;
38       write(STDOUT_FILENO,  &v, sizeof(v));
39     } else {
40       read(STDIN_FILENO,  &v, sizeof(v));
41       v = v + 1;
42       n++;
43       write(STDOUT_FILENO, &v, sizeof(v));
44     }
45   }
46   if (id == 0) {
47     read(STDIN_FILENO,  &v, sizeof(v));
48     fprintf(stderr,"V FINAL VALUE: %d\n",
49 v);
50   }
51   return 0;
52 }
53
54 int i_previous(int i, int np) {
55   if (i > 0) return (i-1)
56   else if (i == 0) return (np-1);
57 }
```

(1,0 points = 0,6 + 0,4)

7

a) Draw the communication diagram that is generated between the processes created with `fork()`



b) Explain what will be printed by statement `fprintf` on line 48?

fprintf on line 48 prints "5" because P0 sends to P1 value 0, P1 sends to P2 value 1 and P2 sends to P0 value 2. As nt is 2 then another turn around is done, P0 send 3 to P1, P1 sends 4 to P2 and P2 sends 5 to P0 that finally prints it

8. Given the following content listing of a directory on a POSIX system :

```
drwxr-xr-x   2 pepe     student         4096 ene  8     2013  .
drwxr-xr-x  11 pepe     student         4096 ene 10     14:39 ..
-rwsr-xr-x   1 pepe     student      1139706 ene  9     2013  copy
-rwxr-sr--   1 pepe     student      1139706 ene  9     2013  append
-rw-------   1 pepe     student       634310 ene  9     2013  f1
-rw----rw-   1 pepe     student       104157 ene  9     2013  f2
-rw-rw----   1 pepe     student       634310 ene  9     2013  f3
```

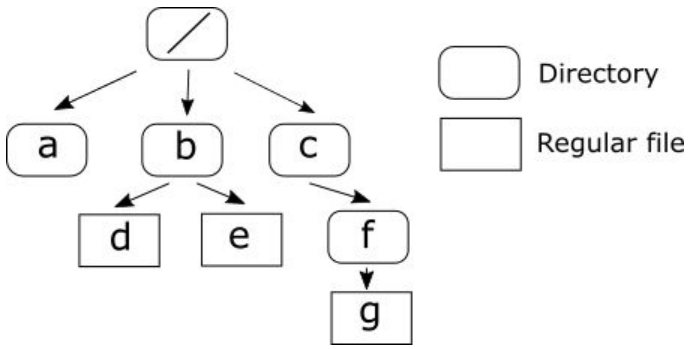
Where `append` and `copy` programs require the names of two files as arguments. The program `append` appends at the end of the file passed as second argument the content first argument file, while `copy` just replaces the content of the file passed as the second argument by the content of the first. Fill in the table and indicate what are the permissions required for the command to succeed and, in case of error, which is the missing permission.

(1,0 points = 0,25 + 0,25 + 0,25 + 0,25)

8

User	Group	Command	Does it work?
ana	**teachers**	**./append f1 f2**	**NO**
Explain In order to execute the command execution permission on "append" is required, reading permission on f1 and writing permission one f2. It fails because execution permission on "append" is lacking, because "ana" is not the owner and does not belong to the owner's group so the third permission set applies and it doesn't include execution			
ana	**teachers**	**./copy f2 f4**	**YES**
Explain In order to execute the command execution permission on "copy" is required, reading permission of f2 and writing permission on the directory (.) because f4 does not exist. (ana, teachers) can execute "copy" and then becomes (pepe, teachers), due to the change of the effective user to the file owner so the process can both read f2 and write into the directory (.) to create f4			
pau	**student**	**./append f2 f3**	**NO**
Explain In order to execute the command execution permission on "append" is required, reading permission on f2 and writing permission on f3. It fails when the process tries to read f2, because group "student" has no reading permission of f2			
pepe	**student**	**./copy f3 f1**	**YES**
Explain In order to execute the command execution permission on "copy" is required, reading permission of f3 and writing permission on f1. The owner (first permission set) has all permissions to execute the command and it has reading and writing permissions on both f3 and f1			

9. A Minix file system contains the following file tree:



(1,2 points = 0,5 + 0,7)

9

a) Indicate the content of every directory in this file system, assuming that the i-nodes occupied by every element are : a(4), b(5), c(8), d(12), e(22), f(10) and g(16)

/

1	.
1	..
4	a
5	b
8	c

a

4	.
1	..

b

5	.
1	..
12	d
22	e

c

8	.
1	..
10	f

f

10	.
8	..
16	g

b) Consider zones of 1 KByte, 32-bit zone pointers, and i-nodes with 7 direct pointers, 1 single indirect pointer and 1 double indirect pointer, obtain the number of zones occupied by the *d* file if its size is 2 MBytes.

2 MBytes / 1 KByte = 2048 zones ----> 2048 pointers to zone

The 7 direct pointers address 7 zones = 7 KBytes

The single indirect points to a zone of pointers with 1024 Bytes / 4 Bytes = 256 pointers

Up to now we have: 7 KB + 256 KB = 263 KB, they remain to be addressed: 2048 KB - 263 KB = 1785 KB that have to be addressed with the double indirect pointer requiring:

1785 KB / 256 = 6,97 -> 7 zones for 2nd level pointers

The file occupies then: 2048 zones for content + (1 zone of single indirect that contains 256 pointers to zone + 1 zone of double indirect that contains 7 pointers to zone + 7 zones that contain 1785 pointers to zone) = 2057 zones