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School of Information Technology and Electrical Engineering

EXAMINATION

Semester Two Final Examinations, 2015

CSSE2310 / 7231 Computer Systems Principles and Programming

This paper is for St Lucia Campus students.

Examination Duration: 120 minutes

Reading Time: 10 minutes

Exam Conditions:

This is a Central Examination

This is an Open Book Examination

During reading time - writing is not permitted at all

This examination paper will be released to the Library

Materials Permitted In The Exam Venue:

(No electronic aids are permitted e.g. laptops, phones)

Calculators - Any calculator permitted - unrestricted

Materials To Be Supplied To Students:

Instructions To Students:

Additional exam materials (eg. answer booklets, rough paper) will be provided upon request.

Answer all questions. Use the C99 version of the language. All numbers should be read as base 10 unless preceeded by 0x.

For Examiner Use Only

Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	

Total _____

Question 1) Write shell commands to do the following: [10 marks (2 each)]

A) Show the first line of the file `ferret`.

```
cat ferret | head -n 1
```

B) Show the directories which will be searched for commands to run.

```
echo $PATH
```

C) Show the first column of the file `ferret` (columns are separated by commas).

```
cat ferret | cut -d ',' -f 1
```

D) Show all instances of `vim` currently running on the system.

```
ps -e | grep "vim" | tr -s ' ' | cut -d ' ' -f 5
# Or
pgrep -l vim
```

E) Count how many files in the current directory have names containing at least 5 characters.

```
ls -ad ?????* | wc -l
```

Question 2) Write C to declare `foo` as . . . : [5 marks (1 each)]

A) An integer variable which will not store negative values.

```
unsigned int foo;
```

B) A pointer to an arbitrary type.

```
void *foo;
```

C) An array of 12 true/false values.

```
bool foo[12];
```

D) A pointer to a function which takes an array of strings and returns a string.

```
char *(*foo) (char *[])
```

E) A pointer to a function which takes two parameters (of the same type as `foo` from Part D) and returns a function pointer (also the same type as from Part D).

```
typedef (char*)(*)(char**) partd;
(char*) (* (*foo)(bar, bar))(char**);
```

Question 3) What is the output from the following statements [10 marks (1 each)]

A)

```
int a=13;
int b=20;
b=b+a*2;
printf("%d", b);
```

B)

```
int a=15;
int b=9;
b+=a-b;
printf("%d %d",a, b);
```

C)

```
int a=7;
int b=4;
switch (a & b) {
case 1: a++; break;
case 2: b=2; break;
case 3: a--; break;
case 4: a==3;
case 5: ++a; break;
default:
b--;
}
printf("%d %d", a, b);
```

D)

```
int a=0;
for (int j=0;j<12;++j) {
    if (j%3) {
        continue;
    }
    a++;
}
printf("%d %d", a, j);
```

E)

```
int a=17;
printf("%d", a++ - 3);
```

F)

```
int a[]={1,4,9,16,25};
int* b=&a[1];
printf("%d", b[1]);
```

G)

```
int a=7;
while (a>0) {
    a--;
    if ((a%2==1) || (--a))
   {
        continue;
   }
    a--;
}
printf("%d", a);
```

H)

```
int a=5;
int b=3;
float c=a/b;
printf("%f", c);
```

I)

```
int a=7;
int b=2;
float c=1.5+a/b*1.5;
printf("%f", c);
```

J)

```
int a=5;
int b=3;
int c=12;
c=c^(b&c);
printf("%d", c);
```

Question 4) The following system uses 4KB pages (4096Bytes) and a two level page table. [5 marks] All addresses are given base 10.

A) Suppose process A has the following page table: [2 marks]

Page	**Frame**
0	Invalid
1	Invalid
...	Invalid
24	100
25	19
26	18
27	20
28	101

What physical address correspond to the following virtual addresses:

i) 102419

page = 102419/4096 = 25.0046 = 25;
offset = 102419%4096 = 19;
phy = 19*4096 + 19 = 77843

ii) 106495

page = 106495/4096 = 25.99975 = 25;
offset = 106495%4096 = 4095;
phy = 19*4096 + 4095 = 81919

iii) 106496

page = 106496/4096 = 26 = 26;
offset = 106496%4096 = 0;
phy = 18*4096 + 0 = 73728

iv) 106515

page = 106515/4096 = 26.00463 = 26;
offset = 106515%4096 = 19;
phy = 18*4096 + 19 = 73747

B) Assuming that the TLB starts out empty, how many pages in the page table must be accessed to read from the virtual addresses given above? Assume the reads happen immediately after each other. [2 marks]

i) 2

ii) 1

iii) 2

iv) 1

C) If process A reads from virtual address 7418, which signal (if any) will the kernel send to it?
[1 mark]

This has a corresponding physical of 1 which is invalid so the kernel should send (the dreaded) SIGSEGV (11)

Question 5) [8 marks]

A) Consider the following listings for a partition which uses 1KB blocks :

```
/$ ls -lih /
275201 drwxr-xr-x 2 jfenwick jfenwick 4.0K Sep 12 11:30 bin
275202 drwxr-xr-x 2 jfenwick jfenwick 4.0K Sep 12 11:30 docs
275203 drwxr-xr-x 2 jfenwick jfenwick 4.0K Sep 12 11:30 tmp

/$ ls -lih /bin
275206 -rwxr-xr-x 1 jfenwick jfenwick 1006K Sep 12 11:30 bash
275205 -rwxr-xr-x 1 jfenwick jfenwick   51K Sep 12 11:30 cat
275204 -rwxr-xr-x 1 jfenwick jfenwick  116K Sep 12 11:30 ls
275213 -rw-r--r-- 2 jfenwick jfenwick   693 Sep 12 11:30 process.sh
275207 -rwxr-xr-x 1 jfenwick jfenwick   91K Sep 12 11:30 ps
275211 -rw-r-xr-x 2 jfenwick jfenwick   342 Sep 12 11:30 startup.sh

/$ ls -lih /docs
275212 -rw-r--r-- 1 jfenwick jfenwick 4.0K Sep 12 12:02 ass3_rules.tex
275199 -rwxr--r-- 1 jfenwick jfenwick  31K Sep 12 11:07 ass4_spec.tex
275215 -rw-r--r-- 1 jfenwick jfenwick 2.3K Sep 12 11:29 draft_instructions
275210 -rw-r--r-- 2 jfenwick jfenwick 7.3K Sep 12 11:17 instructions
275210 -rw-r--r-- 2 jfenwick jfenwick 7.3K Sep 12 11:17 instructions.backup
275219 -rw-r--r-- 1 jfenwick jfenwick 6.4K Sep 12 11:48 instructions.beta
275208 -rwxr-xr-x 2 jfenwick jfenwick  693 Sep 12 11:23 process.sh
275196 lrwxrwxrwx 1 jfenwick jfenwick   10 Sep 12 11:47 process.sh_backup -> process.sh
275218 -rw-r-xr-x 1 jfenwick jfenwick  511 Sep 12 11:59 script.sh
275209 lrwxrwxrwx 1 jfenwick jfenwick   17 Sep 12 11:28 startup.sh -> ../bin/startup.sh
```

Adding up the file sizes in `/tmp` gives $26K$.

i) `instructions.backup` is intended as a backup of the current `instructions`. Why is it a bad idea to use if for this purpose? [2 marks]

They have been hard linked to each other so any corruption in the original will also appear in the back up, and vice versa

ii) Which command was used to create `process.sh_backup`? [1 mark]

ln -s process.sh process.sh_backup

iii) Which files can `jfenwick` execute in the `/docs` directory? [2 marks]

ass4_spec.tex
process.sh
should we include process.sh_backup (a hard link)

iv) Suppose `rm -rf /tmp/*` is executed by the administrator (root). How much additional diskspace will be available? Explain your answer. [3 marks]

Undetermined. As the block size is 1K, there may be internal fragmentation for some of the files.

E.g. temp has 2 files:
File A (1.5 K)
File B (24.5K)

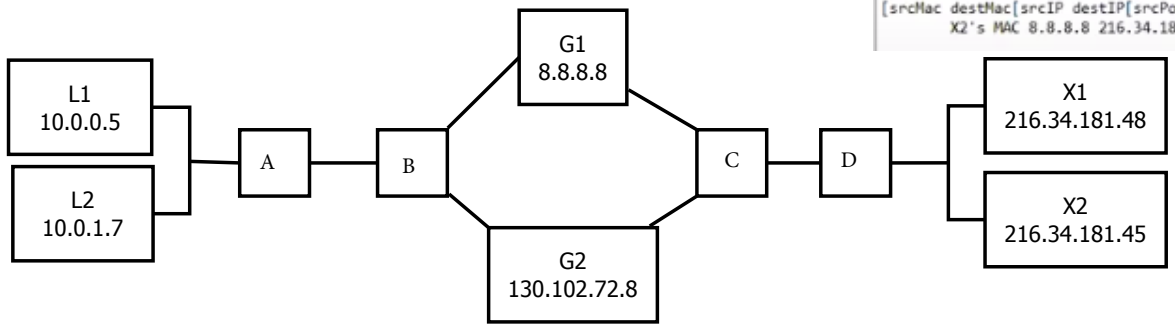
If we delete both file A & B, we would have freed 27K of space/blocks

Also note that hidden files will not be deleted. Therefore some files will not be removed and the corresponding disk space will not be freed

```
L2 -> A -> B -> G1/G2 -> C -> D -> X2:

L2 -> A:
[srcMac destMac[srcIP destIP[srcPort destPort[hello]]]]
        A's MAC 10.0.1.7 216.34.181.45

L2 -> B:
[srcMac destMac[srcIP destIP[srcPort destPort[hello]]]]
        B's MAC 10.0.1.7 216.34.181.45

B -> G1:
[srcMac destMac[srcIP destIP[srcPort destPort[hello]]]]
        G1's MAC 10.0.1.7 216.34.181.45

G1 -> C:
[srcMac destMac[srcIP destIP[srcPort destPort[hello]]]]
        C's MAC 8.8.8.8 216.34.181.45
C -> D:
[srcMac destMac[srcIP destIP[srcPort destPort[hello]]]]
        D's MAC 8.8.8.8 216.34.181.45

D -> X2:
[srcMac destMac[srcIP destIP[srcPort destPort[hello]]]]
        X2's MAC 8.8.8.8 216.34.181.45
```

Question 6) [17 marks]

A) Consider the following network links:



i) For each source and destination below, fill in the table of how many source IP addresses, destination IP addresses and destination MAC addresses will be involved in the transport of a UDP message travelling from source to destination? [3 marks]

Source	Dest	Number of Source IPs	Number of Destination IPs	Number of Destination MACs
L1	L2	1	1	1
L2	X2	2	1	6

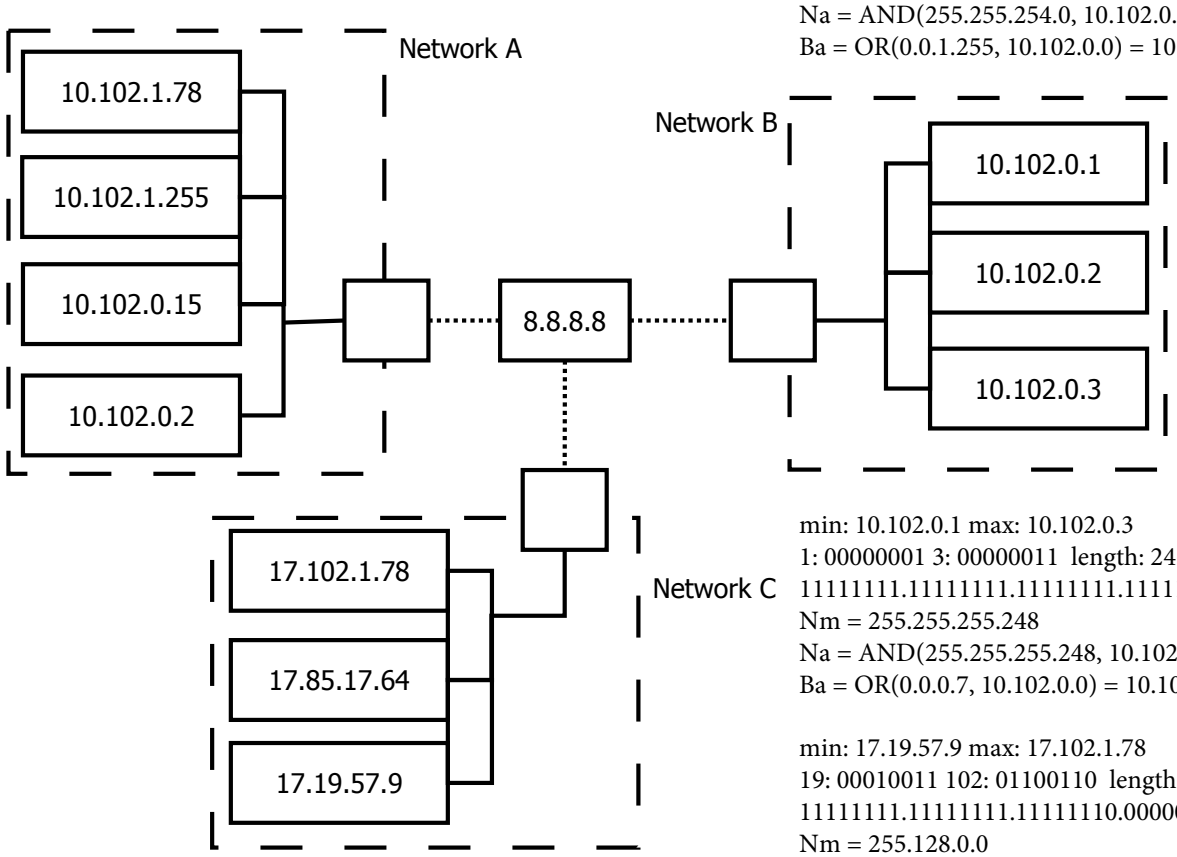
ii) There is an upper limit on the number of nodes between L2 and X2 if they are to communicate. What determines this upper limit? [2 mark]

Yes, the time-to-live which is the number of hops that a packet is permitted to travel before being discarded.

iii) If X1 and X2 had their IP addresses changed to 192.168.1.1 and 192.168.1.2 respectively; what else would need be true about the network shown above? [2 marks]

192.168.0.0 are private IP addresses. Therefore there will needed to be an additional router to NAT these addresses if X1 and X2 want to communicate to the internet.

B) Consider the following



min: 10.102.0.2 max: 10.102.1.255
0: 00000000 1: 00000001 length: 16+7=23
11111111.11111111.11111110.00000000
Nm = 255.255.254.0
Na = AND(255.255.254.0, 10.102.0.2) = 10.102.0.0
Ba = OR(0.0.1.255, 10.102.0.0) = 10.102.1.25

min: 10.102.0.1 max: 10.102.0.3
1: 00000001 3: 00000011 length: 24+5=29
11111111.11111111.11111111.11111000
Nm = 255.255.255.248
Na = AND(255.255.255.248, 10.102.0.1) = 10.102.0.0
Ba = OR(0.0.0.7, 10.102.0.0) = 10.102.0.7

min: 17.19.57.9 max: 17.102.1.78
19: 00010011 102: 01100110 length: 8+1=9
11111111.11111111.11111110.00000000
Nm = 255.128.0.0]
Na = AND(255.128.0.0, 17.19.57.9) = 17.0.0.0
Ba = OR(0.127.255.255, 17.0.0.0) = 17.127.255.255

i) Assume that the three networks indicated in the diagram use the smallest possible subnets (ie smallest number of addresses). Give the network and broadcast addresses for those subnets as well as the number of bits in the host part of addresses. [4 marks]

Network	Network address	Broadcast address	Host bits
Network A	10.102.0.0	10.102.1.255	9
Network B	10.102.0.0	10.102.0.7	3
Network C	17.0.0.0	17.127.255.255	23

ii) Something is wrong with the collection of networks above. What is it? [2 marks]

If you work out B the same as network A (where the 9 host bits makes you use the broadcast address) then you have the same issue.
Also the network address is the same for both A and B which is an issue because these networks are attached to a DNS server which won't know where to send the packets if someone asks for 10.102.0.0.

C) A student's server has crashed and they quickly restart it, however the server is unable to use the port they previously used. What have they forgotten to do? [2 mark]

Forgot to use the setsockopt() function with SO_REUSEADDR as an option

D) Which layers of the network stack do the following belong to? [2 marks]

Term	**Layer**
Internet Explorer and Safari	application
SCP	application
MAC	link/network
Ports	transport

Possible layers: Onion, Link, Physical, Gooey Caramel, Secure, Network, Putty, Application, Transport, Metaphysical.

Question 7) Consider a "unix" filesystem where: [6 marks]

- All i-nodes are cached in RAM
- i-nodes have 10-direct pointers, 2 indirect pointers and 3 double indirect pointers.
- Blocks are 8KB
- Block pointers are 16Bytes
- blocks are numbered from 0.

A) What is the maximum possible file size for this file system? [2 marks]

block size: 8*1024 = 8192 bytes
no.block pointers: 8192/16 = 512
max: 10*8192 + 2*512*8192 + 3*512^2*8192
= 6450921472 bytes or 6299728 KiB
or max: 10*8 + 2*512*8 + 3*512^2*8
80 8192 6291456

B) How many blocks (in total) must be accessed to read the following blocks from a file:
$0, 1, 2, 4012, 8009$ [2 marks]

Block 0 ⇒ Direct block 0 Block 1 ⇒ Direct block 1 Block 2 ⇒ Direct block 2

Block 4012 We want to find: l1,l2,l3 in the equation 4012 = 1033+(l1229+l2219+l3209) Where l1,l2,l3 represent respective the double indirect, single indirect and direct pointer count. We want to use the largest (non-negative) values for l1,l2,l3. Clearly l1=0 since l1increases the pointer count by 2^18. So 4012 = 1033+(0*2^2*9+l2*2^1*9+l3*2^0*9)
2978 = l2*2^1*9+l3*2^0*9
Largest value for l2 is l2=floor(2978/2^9)=5 Meaning 2978 = 5219+l3*2^0*9 l3=418
Thus Double Indirect [0] -> Single Indirect [5] -> Direct [418] ⇒ Block 4012
Similar reasoning Double Indirect [0] -> Single Indirect [13] -> Direct [350] ⇒ Block 8009

C) What is the number of the first block in a large file which needs to use the second double indirect pointer?

[2 marks]

10*8 + 2*512*8 + 1*512^2*8
= 2105424 KiB
no. block: 2105424/8 = 263178
263178
size: 263178*8 = 2105432 KiB

Question 8) [6 marks]

Consider the following code which process A executes:

```
int main(int argc, char** argv) {
    pid_t me=getpid();
    for (int i=0;i<4;++i) {
        fork();
    }
    // line X
    int s;
    if (getpid()==me) {
        while(wait(&s)>=0) {}
    }
    exit(0);
}
```

A) When process A reaches line X, how may children does A have? [1 mark]

4

B) How many processes are **created** overall? [1 mark]

2^4 - 1= 15

C) Draw a fork/process diagram showing the lifetimes of the processes above. [4 marks]

Question 9) In all of the following you may omit `#include`s. You may assume that all system calls succeed. You do not need to consider integer overflow. You may write additional functions to call.

Implement a function `int sarray(int n, int t, int* values)` which takes an array (`values`) containing `n` integers and returns the sum of those integers. The `t` parameter determines how many threads to use for the calculation. For example:

```
sarray(100, 2, v)
```

would add up the first 100 values in v using 2 threads.

Your code must use the threads effectively and your code must be thread-safe. [8 marks]

Question 10) In all of the following you may omit `#includes`. You may assume that all system calls succeed and that all processes exit normally. You may assume all named files exist and are readable. You may assume that all lines in files have 79 or fewer characters.

This question deals with a program `tops n file1 ...` which takes two or more arguments. The first argument (n) indicates a number of lines. The second (and further arguments) are file names. For each file (in order), print out the first `n` lines from the file (if the whole file were sorted). For example:

file1:	file2:
Z	X
A	Q
B	H

`tops 2 file1 file2` would output:

```
A
B
H
Q
```

[25 marks]

A) Implement a function `load_and_sort` which takes a `FILE*`, reads all the lines from the file into an array of strings, then sorts them. It should return the sorted array. Hint: You may make use of the standard C `fgets` and `qsort` functions. [6 marks]

```
char** load_and_sort(FILE* f) {
```

B) Implement the `tops` program described at the beginning of this question.

For this part, you may assume that the `load_and_sort` function from part A exists and functions correctly. You should execute each call to `load_and_sort` in a separate thread and run them concurrently. The order of the output must be correct however. [7 marks]

C) Implement a function `ptops(int n, const char* fname)` which outputs the first (sorted) `n` lines from file `fname`. You will make use of the `head` and `sort` external programs.

You are not permitted to use the `system()` or `popen()` c functions. [8 marks]

```
void ptops(int n, const char* filename) {
```

D) Implement the `tops` program described at the beginning of this question.

Use the `ptops()` function from part C to deal with each file. (Individual files do **not** need to be processed concurrently). The order of the output must correct however. [4 marks]

END OF EXAMINATION

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