IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2016

MSc in Computing Science
for Internal Students of the Imperial College of Science, Technology and Medicine

PAPER M2

COMPUTER SYSTEMS

Friday 29 April 2016, 14:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators required

Section A (Use a separate answer book for this Section)

1 This question has 5 parts.

a Simplify the following Boolean expression to its simplest form (fewest number of literals): $E = A \bullet B + A \bullet B \bullet C + A \bullet B \bullet C \bullet D + A \bullet B \bullet C \bullet D \bullet F$, where $\bullet$, $+$, and $'$ represent "AND", "OR" and "NOT" operations respectively. Please show the sequence of steps and state the reduction rules used.

b Briefly describe what is a *multiplexer* in the context of digital circuits and what its uses are.

c Briefly describe the *Big Endian* and *Little Endian* formats for storing data in memory. Show how an Integer 36509_{10} (hexadecimal value of $8E9D_{16}$) is stored in 32-bit memory in both of the above formats.

d Consider a main-memory which is byte-addressable and consisting of 4G rows, where each row is 32-bits wide. This memory is built using RAM chips, where each chip contains 512M rows and each row is 4-bits wide. For this particular memory organisation, evaluate the following and explain your result.

i) Total size of the main memory,

ii) Total number of memory modules,

iii) Total number of RAM chips.

Assuming memory modules are numbered from 0, 1, 2, and so on, in which memory module will the byte address 23_{10} be found if the memory system uses the following addressing modes:

iv) High-order interleave,

v) Low-order interleave.

e A number stored using the IEEE Single Precision format is stored in memory as $7FA48000_{16}$. Convert this number into binary and decimal. Show your reasoning clearly.

The five parts carry, respectively, 15%, 15%, 20%, 25%, and 25% of the marks.

Section B *(Use a separate answer book for this Section)*

2a i) What are the three components of the Central Processing Unit (CPU)?

ii) What is the main advantage of register-to-register instructions relative to register-to-memory-location instructions?

iii) Why is DMA I/O more efficient than interrupt-driven I/O?

b i) Name two basic instructions (operations) for stack memory.

ii) Give the generic name of the register that contains the memory address of the next instruction to be executed.

iii) Give the generic name of the instruction that unconditionally forces the program execution to start with a specific instruction stored in the memory.

iv) Explain how function call and return can be achieved using the instructions named in the above parts i) to iii).

v) Stack memory is used to enable program (function) calls. For the following nested program calls, use a diagram to illustrate the contents of the stack frame (also known as the activation record) when the program execution reaches the point marked. The return addresses, variables and their values, caller's frame pointers (e.g., by use of base pointer register, ebp, as in the Pentium architecture) and the current stack pointer are expected to be provided in your diagram. Use arrows to link the return addresses in the stack to the corresponding program statements where instructions will resume upon return.

```
Void Alpha () {
      Beta (23)
      statements
}
Void Beta (int x) {
int a, b
Gamma (55, 77)
statements
}
Void Gamma (int m, n) {
int a
statements    ← Execution reaches the first of these statements
}
```

The two parts carry, respectively, 25% and 75% of the marks.

Section C (Use a separate answer book for this Section)

3a i) Briefly describe the concept of a process within an operating system, by discussing what constitutes the context of a process.

ii) What are threads and briefly explain their advantages compared to processes?

b A printer manager in an operating system controls 5 printers. When a client process wants to print it requests a printer from the printer manager which returns the printer name if there is a free printer, else the client process blocks until a printer is free. It releases the assigned printer after printing a file. The print manager supports the following calls:

```
string request ( )  // returns name of allocated printer

release (string name)  // releases printer for re-allocation

void init ( )
```

where name is a string, init is an internal procedure to the printer manager, but request and release are called by client processes.

Assume:
the operating system supports the semaphore operations
down (semaphore s), up (semaphore s), initsem (int n, semaphore s)
where s is a semaphore and n is an initial value.

All processes have access to shared memory which contain required semaphores, queue of free printers, counts of free printers, waiting processes etc. Assume shared memory has been attached for all processes.
Hint: Use an array of printer names for the queue of free printers.

Give outline pseudocode (i.e. syntax is not important) for implementations of:

i) request procedure which blocks the calling process if all printers are in use and returns the name of the printer when there is a free one;

ii) release procedure which releases the named printer for allocation;

iii) init which initialises semaphores, counts and the printer queue. Assume printer names are printer1, printer2 etc.

The two parts carry, respectively, 35% and 65% of the marks.

Section D (Use a separate answer book for this Section)

4 This question has 5 parts.

a Briefly describe the three different page table types: *Hierarchical*, *Hashed* and *Inverted* with respect to virtual memory.

b Consider a file system with an inode organisation. Suppose that, for a given file, the file system has filled up all the blocks stemming from the doubly indirect pointers. Assume that the inode and free block bitmap are both completely in memory, but there is no buffer cache. How many disk accesses will it take to write one more byte to the file?

c Explain what direct memory access (DMA) is and why it is used. Although DMA does not use the CPU, the maximum transfer rate is still limited. Consider reading a block from disk. Name **three** factors that might ultimately limit the rate of transfer.

d Compare small and large page sizes for a paged virtual memory system. Consider fragmentation, data structure requirements, page tables, page transfer time, TLB space etc.

e Disk requests come in to the disk drive for tracks 10, 22, 20, 2, 40, 6, and 38, in that order. A seek takes 5 ms per track moved. In all cases, the arm is initially at track 20. How much seek time is needed for:

i) First-come, First-served

ii) Shortest seek time first

iii) Scan scheduling (initially moving upwards)

The five parts carry, respectively, 15%, 15%, 20%, 25%, and 25% of the marks.