Queen Mary
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**ECS404U** **Computer Systems and Networks** Duration: $2\frac{1}{2}$ hours

# SOLUTIONS AND MARKING SCHEME

**YOU ARE NOT PERMITTED TO READ THE CONTENTS OF THIS QUESTION PAPER UNTIL INSTRUCTED TO DO SO BY AN INVIGILATOR.**

**Instructions:** This paper contains FOUR questions. **Answer ALL questions.** Cross out any answers that you do not wish to be marked.

Calculators are permitted in this examination. Please state on your answer book the name and type of machine used.

Complete all rough workings in the answer book and cross through any work that is not to be assessed.

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**Exam papers must not be removed from the exam room.**

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**Question 1**

This question is about Computer Architecture

(a) Give short definitions of the following concepts:

(i) microprocessor

(ii) microcontroller

Explain what distinguishes one from the other. **[5 marks]**

**Solution:** A standard bookwork question.

(i) A microprocessor is an integrated circuit that contains all the functions of a central processing unit of a computer (Oxford English Dictionary)

(ii) A microcontroller is a control device that incorporates a microprocessor.

In other words a microprocessor is a computer cpu on a chip. Stand-alone microprocessors are used in devices that require significant computing power. Microcontrollers often include microprocssors that are underpowered compared with standalone microprocessors (slower clock cycles or architectures with smaller numbers of bits). They can be very cheap and are used in low-level devices.

Two marks total for the definitions: one each if reasonable. Three marks for clarity on comparison: 3 marks if approximately as above, 2 if good with some weakness or poor expression. 1 if inadequate but with some correct information conveyed.

(b) Explain whether you would expect the following devices to contain a microprocessor, microcontroller, both, or neither. Give reasons for your answer.

(i) a smartphone

(ii) a burglar alarm

(iii) a television set

(iv) an electric fire

**[5 marks]**

**Solution:** Students have discussed what kinds of computing power different devices need.

(i) a smartphone: probably both. Certainly contains a microprocessor as cpu to handle major computing commitments, eg games. Some more sophisticated devices, eg camera, likely to contain microcontrollers.

(ii) a burglar alarm: a consumer device that nowadays uses digital comms, and may contain a basic mobile phone. Will certainly contain a microcontroller. Probably not sophiticated enough to contain a standalone microprocessor.

(iii) a television set: often now a smart tv running apps. Handling MPEG video compression takes significant computation. CPU hence microprocessor (but not an incredible powerful one) plus microcontrollers.

(iv) an electric fire: typically does not do computation so contains neither.

5: good clear response, showing an appreciation of the different levels of computing power required in different devices

4: good response but with some small issues of clarity or lack of understanding.

3: good response but some significant issues.

2: response not really adequate

1: response inadequate but containing some positive evidence.

(c) One of the ways in which modern computers differ from the von Neumann model is that instead of a single memory, there is a **memory hierarchy**. Explain what is meant by the memory hierarchy. Explain how it is ordered. List three things you would typically expect to find in the memory hierarchy, state how they are ordered in it, and explain why they are in this ordering. **[5 marks]**

**Solution:** Students have covered this kind of issue in class. Question covers knowledge and understanding.

Computers have multiple mechanisms for storing data. These include registers on the cpu, the main memory, long-term storage in the form of disks and various levels of cache. The hierarchy is ordered by closeness of connection to the cpu, with devices closer to the cpu being higher up the hierarchy and typically having smaller amounts of shorter term storage. This means that cpu registers are at the top of the memory hierarchy, main memory is lower down, and disk is lower still. Cpu registers are actually on the cpu, storing information currently being computed with. The main memory is often either directly connected to the cpu, or is closely linked to it. Disk storage is more distant from the cpu and connected via a disk controller.

Two marks for the definition of the memory hierarchy, reducing to one if unclear or contains inaccuracies. One mark for ordering. Two marks for examples and explanation, reducing to one if errors in examples or explanation, with zero if errors significant.

(d) Define the notion of **cache** as used in computer architecture and give two examples of computations, one illustrating when such a cache is efficient and one illustrating when it is inefficient. Explain why in each case. **[5 marks]**

**Solution:** Definitions and examples are standard bookwork:

A cache is a system that keeps small amounts of information that is normally inaccessible in a relatively accessible piece of storage, so that it can be accessed relatively quickly on need. This works well when the data needed is relatively predictable, typically because the data in use is fairly static or because the data needed is physically close to data in use.

Examples of computations where a cache can be efficient include ones where most of the time is spent in tight loops, and ones where it is less efficient include ones where there are lots of unpredictable method calls. Similarly it is efficient for calculations on matrices where the matrices are accessed in row order (assuming they are kept in row order). It is inefficient for calculations where the matrices are accessed in column order.

2 marks for the definition, 1 if unclear or contains errors.

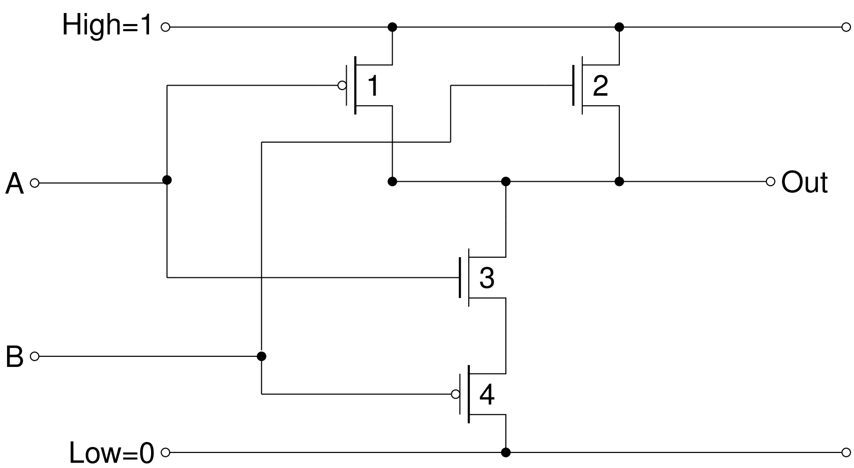
3 marks for examples, 2 if minor errors or somewhat unclear, 1 if major errors or very unclear.

(e) The diagram below depicts a logic gate.

(i) Explain the difference between the transistors labelled 1 and 2.

(ii) When A is High (1) and B Low (0), explain which transistors are on and off.

(iii) Explain what voltage is at Out under those circumstances.




**[5 marks]**

**Solution:**

(i) Transistor 1 is a pmos transistor while transistor 2 is nmos. Transistor 1 is on when its gate is Low (0), and off when its gate is High (1), while Transistor 2 is the reverse, on when its gate is High and off then its gate is Low. This means that as switches, Transistor 1 is closed (giving a connection) when its gate is Low, and Transistor 2 is closed when its gate is High.

(ii) When A is HIgh, then 1 is off and 3 is on. When B is Low, 2 is off and 4 is on.

(iii) Since both 1 and 2 are off there is no connection between High and Out. But since 3 and 4 are on, there is a connection between Low and Out. So the output at Out is Low or 0.

2 marks for first part, one if errors or unclear.

2 marks for second part, one if errors or unclear.

1 mark for last part, 0 if errors or unclear.

## Question 2

This question is about forms of digital representation.

(a) This part of the question is about hexadecimal, binary and text representation.

The following sequence is obtained as the hex dump of the contents of a short text file encoded in UTF-8:

`6162 636a 6b41 4243 4a4b 3031 3233`

Recall that the ASCII code for the character '0' (zero) is $48$, for the character 'A' it is $65$, and for the character 'a' it is $97$ (these are expressed in decimal).

(i) Give the bit sequences represented by:

- The first group of four hex digits: `6162`
- The third group of four hex digits: `6b41`

Explain how you reach your answers.

(ii) Explain the link between ASCII and UTF-8, and also explain why UTF-8 is different from ASCII.

(iii) Explaining your reasoning, what character sequence is represented by the entire sequence given above?

**[10 marks]**

**Solution:**

(i) Each hex digit represents four bits in standard fashion. Translation is digit by digit.

- `6162` = `0110 0001 0110 0010`
- `6b41` = `0110 1011 0100 0001`

(ii) ASCII is a 7-bit character set with codes corresponding to $0 \ldots 127$, UTF-8 is a way of representing unicode. The first 128 points correspond to ASCII, and are 8-bit equivalents of the ASCII representations (ie they are padded with a leading 0). But UTF-8 can also represent the many thousands of other unicode characters, and hence (unlike ASCII) is a variable length system.

(iii) Each character corresponds to 8 bits, or two hex digits. Both numbers and characters are represented sequentially. Hex `3x` is $3*16+x = 48+x$, while `4x` is $4*16+x = 64+x$ and `6x` is $6*16+x = 96+x$. So `6162 636a 6b41 4243 4a4b 3031 3233` is (97)(98)(99)(106)(107)(65)(66)(67)(74)(75)(48)(49)(50)(51), so is "abcjkABCJK0123".

(i) 3 marks total. 2 marks for answers, 1 if minor errors. 1 mark for explanation, 0 if absent, unclear or wrong.

(ii) 3 marks total, 1 marks for link, 1 mark for UTF is unicode and 1 mark for that meaning there are more characters.

(iii) 4 marks total. 2 marks for understanding method (1 if unclear) and 2 marks for accuracy (1 if minor errors).

(b) This part of the question is about binary representation of numbers.

(i) What numbers are represented by the 8-bit sequences `1100 0111` and `0001 0001` when viewed as **unsigned integers**? (Explain your reasoning.)

(ii) What numbers are represented by the 8-bit sequences `1100 0111` and `0001 0001` when viewed as **signed integers** in 8-bit two's complement? (Explain your reasoning.)

(iii) Show that you understand how to perform long multiplication in binary by using it to multiply these two numbers. Give your working.

(iv) What does your answer represent when viewed as an unsigned integer?

(v) What do the eight rightmost bits of your answer represent when viewed as an integer in 8-bit two's complement?

**[10 marks]**

**Solution:**

(i) $1100\ 0111 = 1 + 2 + 4 + 64 + 128 = 199$ and $0001\ 0001 = 16 + 1 = 17$ Don't need much explanation, just some working.

(ii) $1100\ 0111 = 1 + 2 + 4 + 64 - 128 = -57$ and $0001\ 0001 = 16 + 1 = 17$. Initial one is worth $-128$ in 8-bit two's complement. Many methods exist for doing first calculation.

(iii) Long multiplication:

```
       11000111
       00010001   *
   ------------
       11000111
   110001110000
   ------------
      110000000   carries
   110100110111
   ------------
```

(iv) As an unsigned integer the answer is: $110100110111 = 2048 + 1024 + 256 + 32 + 16 + 4 + 2 + 1 = 3072 + 288 + 23 = 3360 + 23 = 3383$

(v) The rightmost eight bits are `0011 0111` which is $32 + 16 + 4 + 2 + 1 = 55$.

(i) 2 marks total, one for results and one for reasoning.

(ii) 2 marks total, one for results and one for reasoning.

(iii) 3 marks total, 2 for clearly understanding method and 1 for accuracy.

(iv) 1 mark total, with 0 if error or unclear.

(v) 2 marks total, one for results and one for reasoning.

(c) For this part question assume that each pixel on a camera is coloured and uses 24-bit colour.

(i) Calculate how much storage is required to store an uncompressed image taken by a 13 Megapixel camera.

(ii) Explain why cameras use compression to store images, name the usual compression algorithm used, and explain why lossy, rather than non-lossy compression is used.

**[5 marks]**

**Solution:**

(i) Each pixel requires 24 bits, which is 3 bytes. We have 13 Megapixels, so this is 39 Megabytes in all.

(ii) This is a lot of storage, and cameras use compression in order to be able to store enough images and video on a single card, or in the storage available. The usual compression algorithm is JPEG and lossy compression is used because, first we do not have to have the exact same image displayed, there is typically enough noise in an image that very small differences can not be noticed. Second, lossy compression allows better compression rates than non-lossy.

(i) 2 marks, 1 for method. 1 for accuracy.

(ii) 3 marks with one for each of explanation, name and lossy v non-lossy.

**Question 3**

This question is about Assembly Language

(a) Considering that data lives in the RAM and calculations happen in the CPU, what bottleneck issues might this create with regards to speed of operations.

**[5 marks]**

**Solution:** A standard bookwork question and predictable. The main issue with such operation is the fact that once calculations are done, results have to go back to the RAM and hence the exchange of data will have to go through physical bus connections with expected delays in such exchange of data. Hence the bus is the slowest part of this operation due to the time it takes for transfer. Even if CPUs are getting much faster the problem with data transfer still exists; however, there are solutions to overcome these issues.

Explanation similar to the above that they clearly specify that the data exchange between the RAM and CPU are the main reason for slow operation should get 3 marks and explaining that CPU speed does not mean solving the problem (2 marks).

(b) Explain what Compilation is in terms of computer programming and how it is linked to Assembly language. **[4 marks]**

**Solution:** Translation from a high level language to machine code is called compilation, rather than assembly; it usually goes through an assembly language and because it is just as hard to write programs which output zeroes and ones as it is to write zeroes and ones directly, compiler programs are comprehensible, so compilers output assembly, which is then assembled into machine code. 2 marks for explaining what Compilation means and then clearly linking it to Assembly Language and machine code (2 marks).

(c) Explain what the MIPS instruction

```
subu $t2 $t0 $t1
```

does, where \$t0, \$t1, and \$t2 are registers. Explain whether the operation can be used on unsigned and signed numbers and if not, what instruction should be used. Now write a MIPS program that will load the values 55 and 31 into registers \$t0, and \$t1, respectively, and use the instruction above to perform the subtraction and therefore store the outcome into memory location y.

**[7 marks]**

**Solution:** The instruction subtracts \$t1 from \$t0 and puts the results in register \$t2. This is mainly used for unsigned numbers and for signed numbers we could use the MIPS instruction 'sub'.

```
li $t0 55
li $t1 31
subu $t2 $t0 $t1
sw $t2 y
```

1 mark for identifying it is subtraction operation for unsigned numbers and 2 marks for mentioning that 'sub' is used for signed numbers. 1 mark for each correct line in the MIPS program written above.

(d) Write a MIPS program that will load the values stored in memory locations x and y into registers $t0 and $t1, respectively, and then perform subtractions on these two signed numbers with the results saved in register $t2.
Then, multiply the outcome of this subtraction by the value in register $t0 and ensure that the full multiplication process outcome is saved into the main memory locations w and z.

**[9 marks]**

**Solution:**

```
lw $t0 x
lw $t1 y
sub $t2 $t0 $t1
mult $t2 $t0
mflo $t3; mfhi $t4
sw $t3 w
sw $t4 z
```

1 mark for each correct loading word instruction. 2 marks for the correct subtraction instruction and 2 marks for the correct multiplication instruction. 1 mark each for each correct mfhi and mflo instruction and 0.5 mark for each corrct store instruction.

**Question 4**

This question is about Computer Networks

(a) Networks work in one of two ways: circuit-based and packet-based networking, Explain each type with examples and define whether modern networks are circuit or packet-based. **[6 marks]**

> **Solution:** Circuit-based: you set up a persistent connection between two points on the network. Classic example: telephones. When you make a call there is a persistent connection between caller and receiver. Packet-based: you send information in individual dollops, each piece contained in a packet which tells the network where to deliver it. Classic example: the postal service Modern networks are mainly packet-based
>
> 1 mark each for defining each type and 1 mark for each example. 2 marks for specifying that modern networks are network-based.

(b) Mention at least one example for each of the following layers in the OSI networking model:

i) application
ii) transport
iii) internet
iv) link

**[4 marks]**

> **Solution:** Application: Domain Name System (DNS) or for example SMTP for e-mailing, Transport: User Datagram Protocol (UDP) or Transmission Control Protocol (TCP), Internet Protocol version 4 (IPv4 or IPv6) and Link: Ethernet.
>
> 1 mark for each correct identified protocol.

(c) If SMTP (Simple Mail Transfer Protocol) is used for sending e-mails, what are the three common protocols used in receiving emails in computer networking? Also mention in your answer the two common mail Messaging Structures standards used.

**[5 marks]**

> **Solution:** IMAP (Internet Message Access Protocol), POP (Post Office Protocol), Exchange (MS version of IMAP). For messaging structure standards, the two common used are Multipurpose Internet Mail Extensions (MIME) and RFC822.
>
> 1 mark for each receiving protocol and 1 mark each for each Messaging Structure correct.

(d) Packets are used in computer networking to encapsulate messages and important information for communications between different machines and ports. What are packets called for TCP (Transmission Control Protocol) and IP (Internet Protocol)?

**[4 marks]**

**Solution:** TCP packets are called segments and IP packets are called datagrams. SMTP is Simple Mail Transfer Protocol used in mailing for sending messages and mainly used on the transmitting side.

2 marks for each correct answer above.

(e) Usually in a TCP packet header a port number is mentioned, what does this number signify and are these ports public or private? The TCP packet header also includes a field for 'checksum'. What is this used for?

**[6 marks]**

**Solution:** Ports tell computer which program the message is for. A port is a 16 digit binary number. Programs that expect communication listen at particular ports. Standard protocols have standard ports. Sometimes a server will start an interaction on a standard public port, then move it to a private one, in order to free it up. So the choice is mainly based on whether a secured communication is needed or not.

The TCP Checksum is used to detect corruption of data over a TCP connection. If a bit is flipped, a byte mangled, or some other badness happens to a packet, then it is highly likely that the receiver of that broken packet will notice the problem due to a checksum mismatch.

2 marks for explaining the function of port number and 2 marks for explaining that they are generally public but could be reserved only for certain communication. 2 marks for explaining the function of Checksum.

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**End of questions**