**BCS THE CHARTERED INSTITUTE FOR IT**

BCS HIGHER EDUCATION QUALIFICATIONS
BCS Level 4 Certificate in IT

**COMPUTER AND NETWORK TECHNOLOGY**

**September 2019**
Time: TWO hours

Section A and Section B each carry 50% of the marks.
You are advised to spend about 1 hour on Section A (30 minutes per question)
and 1 hour on Section B (12 minutes per question

**Answer any Section A questions you attempt in Answer Book A**
**Answer any Section B questions you attempt in Answer Book B**

**EXAMINERS' REPORT**

**General comments on candidates' performance**

*In comparison to previous years, candidates' performance declined considerably. Candidates do have an understanding of the concepts evaluated in this exam, but this understanding not in the depth required. It is recommended that candidates revise using previous exams as well as the textbook indicated in the reading list. Moreover, candidates must understand the difference between "indicate", "describe", "analyse", when used within a question, a "description" and "analysis" requires a thorough answer where the candidate can demonstrate its understanding of the concept.*

## Section A
**Answer 2 questions (out of 4) in Answer Book A. Each question carries 30 marks.**

**A1.**

All numbers in a computer are stored in binary form as strings of 1s and 0s.

a) Why do computers use binary arithmetic with bits representing 0 and 1, rather than decimal arithmetic with digits representing 0,1,2,3 …, 9?

**(5 marks)**

b) How can negative numbers be represented in a computer using only 0s and 1s? Describe two different widely-used representations of negative values.

**(5 marks)**

c) Computers can handle both integer numbers and floating-point numbers. In general, separate arithmetic units (and even separate machine-level instructions) are required for integer and floating-point operations. Why is it necessary to treat integer and floating-point numbers so differently?

**(10 marks)**

d) The IEEE standard for floating-point arithmetic represents a floating-point value in 32 bits in the form

$N = (-1)^S \times 1.F \times 2^{E+B}$

Where N is the floating point-number, S is the *sign-bit*, F the *fractional mantissa*, E the *exponent*, and B the *bias*. Explain the meaning of each of these terms as they relate to the floating-point format.

**(10 marks)**

**Answer Pointers:**

a) People use base 10 with ten symbols 0, 1, 2, … 9. It is possible to build digital computers using ten symbols (i.e., 10 different voltage levels), but it would not be cost-efficient. Each symbol would have to be represented by a different voltage level, and that would require devices that can create, store, manipulate, and detect 10 levels of voltage. Current technology does not let us do this.

By using binary or base 2 arithmetic, we need only two symbols: 0 and 1 (off and on). Modern technology allows us to create very reliable binary digital devices. These binary devices can be produced very cheaply; a modern advanced microprocessor has of the order of a billion binary logic elements on a single silicon chip.

Note that some computers use BCD (binary coded decimal). Here, binary digital devices are used, but numbers are coded as decimal digits using 4 bits (i.e., 0000 = 0 to 1001 = 9). BCD is largely used only in financial calculations.

b) We represent negative numbers in everyday life by placing a minus sign in front of a number. Computers encode signed (positive and negative numbers) into a string of bits.

You cannot tell whether a string of bits represents a negative or a positive number or either whether it is signed or unsigned. You need to know what convention has been used to create (encode) the string of bits. Typical conventions are:

**Sign and magnitude**: This is rather like the human representation of signed numbers. The leading (left-most) bit is a sign bit. 0 represents positive and 1 negative. In five bits 0101 is +5 and 1101 is -5. The value 00000 is +0 (zero) and the value 10000 is -0.

Sign and magnitude representation is not normally used to represent signed integers because it requires more complex hardware to construct arithmetic logic units. Moreover, as we have stated, there are two values for 0; that is, 000…0 = +0 and 100…0 = -0. Of course, +0 and -0 are the same, but this notation complicates the design of comparators and it reduces the range of numbers by 1. Note that sign and magnitude representation is used to represent the mantissa in floating-point arithmetic.

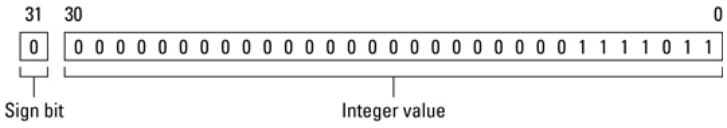
**Two's complement arithmetic**: This is the normal way of representing signed integers in all modern computers. The two's complement value of -N is given by $2^n - N$, where n is the number of bits on the word. For example, if n = 5 bits, then +3 = 00011 and -3 = 32 – 3 = 29 = 11101 (that is -3 is represented by 11101). In practice, generating a two's complement number is easy, you invert all the bits and add 1.

The major advantage of two's complement arithmetic is that you do not require separate adders and subtractors. Adding a complement is the same as subtraction. To perform X – Y, you simply add X to the complement of Y.

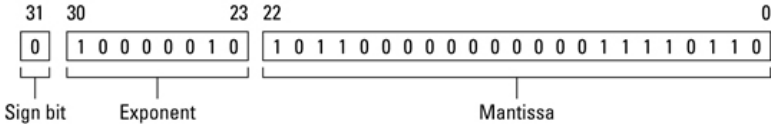
Moreover, negative numbers all have a 1 as a sign bit, which make testing a number easy. All computers used two's complement arithmetic to represent signed integers.

NOTE that one's complement arithmetic is very similar to two's complement (the systems differ in 1 bit). However, one's complement arithmetic is little used today.

c) An integer exists inside the computer as a true binary value. For example, the value 123 is stored in modern computers as a 32-bit value. The sign bit determines whether the value is positive or negative (0 is positive, and 1 is negative). The rest of the 31 bits are used to represent the value. See image below:




A floating-point number, however, cannot exist in a computer that uses binary (1s and 0s). So, the floating-point number is cleverly faked. First comes the sign bit: 1 for negative or 0 for positive. The exponent is used with the mantissa in a complex manner to fake floating-point values in binary. See image below:




d) Floating-point arithmetic is far more complicated. A floating-point value is represented by

$(-1)^S$ x 1.F x $2^{E + B}$ where S is the sign bit, F the fractional mantissa, E the exponent and B the bias.

The sign of a binary floating-point number is represented by a single bit. A 1 bit indicates a negative number, and a 0 bit indicates a positive number.

It is useful to consider the way decimal floating-point numbers represent their mantissa. Using $-3.154 \times 10^5$ as an example, the sign is negative, the mantissa is 3.154, and the exponent is 5. The fractional portion of the mantissa is the sum of each digit multiplied by a power of 10:

$.154 = 1/10 + 5/100 + 4/1000$

A binary floating-point number is similar. For example, in the number $+11.1011 \times 2^3$, the sign is positive, the mantissa is 11.1011, and the exponent is 3. The fractional portion of the mantissa is the sum of successive powers of 2. In our example, it is expressed as:

$.1011 = 1/2 + 0/4 + 1/8 + 1/16$

IEEE Short Real exponents are stored as 8-bit unsigned integers with a bias of 127. Let's use the number $1.101 \times 2^5$ as an example. The exponent (5) is added to 127 and the sum (162) is stored in binary as 10100010.

**Examiners' Comments:**

*For section 1a, there is evidence that many candidates tried to talk about digits rather than the way it can/may be represented in the computer system. Due to this, they missed the expected discussion about signal levels representing different voltage values, etc. This is likely due to two factors: (1) candidates are not prepared for the challenge of the exam and were unable to explore the subjects or (2) some candidates listed everything they could, e.g. 0-15 representing in binary table.*

*For sections 1b, 1c, 1d: These 3 sub-questions are interrelated, e.g. using questions related to negative numbers, etc. When some candidates have tried to derive the answer to the question from the question of another part of the same question, this created a chain effect. If part b was incorrect then the rest of the elements would be also incorrect.*

**A2.**

a) In the context of computer architecture and assembly language, what is indexed addressing (also called pointer-based or register-indirect addressing). How is it used and why is it so important to the programmer?

**(10 marks)**

b) A region of a microprocessor's memory contains a consecutive sequence of integers, from memory location FIRST to location LAST.

Write an assembly language program to read each of these numbers one by one to determine the largest integer. Put the largest integer in the location following LAST.

You may choose any assembly language you want for this problem. You may even invent your own assembly language. However, you must clearly explain the operation of each assembly language instruction and say what it does.

**(20 marks)**

**Answer Pointers:**

a. The very early computers used direct addressing to access an operand; for example, ADD A,1234 which would add the contents of memory location 1234 to the contents of the accumulator. Since the address 1234 is fixed in the instruction, you can't use the same instruction (in a loop) to add a sequence of values in a list in memory.

In indexed addressing (pointer-based addressing), the address of an operand is in a register (called a pointer register, address register or index register). Thus, ADD A,(X) is an instruction that adds the contents of memory whose address is in the X register to the accumulator. NOTE that two operations are required to access the operand: first read the contents of X and then read the contents of memory pointed at by the contents of X.

This instruction may be written in various ways (depending on the processor); e.g., LDR r0,[r3] in ARM assembly language loads register r0 with the contents of memory pointer at by register r3.

Because the pointer register can be modified, addresses can be accessed sequentially. For example, to add a sequence of consecutive values might require code like:

```
Setup pointer to first address in X
Loop ADD A,(X)   ;add memory value pointed at by X register
INC X            ;point to next address
Until X = end address
```

This above code is a mixture of assembly language and pseudocode
Without indexed addressing, the only way to access tables/lists/vectors would be via self-modifying code.

b. The pseudocode for this operation is

```
      Set current largest value to Large = 0
      Point to first location FIRST
Loop  Read value at pointer
      IF bigger than Large THEN Large – new value
```

```
Increment pointer
Until pointer = LAST + 1
Store Large at LAST + 1
```

In assembly language we can write

```
     CLR D0       ;set register D0 to 0, D0 holds current largest
value
     MOVE A0,First ;Pointer register A0 contains location for First
element
Loop MOVE D1,(A0}  ; read element pointed at into register D1
     CMP  D1,D0    ; compare largest with new element
     BLT  Nxt      ; if smaller skip save
     MOVE D0,D1    ; if larger save new large value in D0
Nxt   ADD   A0,#1      ; increment the pointer tom point to next
element
     CMP  A0,Last+1 ;test for end of loop
     BNE  Loop     ; if not end then continue
     MOVE (A0),D0  ; Save largest value in memory
```

**Examiners' Comments:**

*Based on the exam answers it appears that the candidates did not understand the question.*

**A3.**

a) What is an operating system; why is it necessary on a general-purpose computer, and what facilities does it provide?

**(12 marks)**

b) In the context of operating systems:

1. What is virtual memory?
2. Why is virtual memory necessary?
3. How is virtual memory implemented?

**(18 marks)**

**Answer Pointers:**

a) Early computers did not have operating systems. Each job (program) was loaded into the computer and executed. Then, another program was loaded and executed. The operating system is not necessary in an environment with one program.

As time progressed, computers executed more than one program. A special system program was designed to perform the task of loading user programs, ensuring their execution, and dealing with errors (by killing the program and starting a new program).

Programs use resources (printers and keyboards, disk stores etc). In a single-program environment, each program must include the code for every device it needs to interact with. The modern operating system contains all the necessary device drivers, which means that individual programs do not need to know how to perform I/O or store data on disk drives. All the program needs to know is how to request an operating system function.

This the operating system is a program that controls all aspects of the computer. It loads and terminate user programs, it controls all I/O and storage devices (including network communications). It also allows multiple programs to be run simultaneously by switching between programs (multitasking).

Today's operating systems also provide a user interface to simplify control of the computer. Most computers have a user interface that is based on windows and a mouse (plus a keyboard). Programs can be started by clicking an icon and data moved by dragging icons with a mouse.

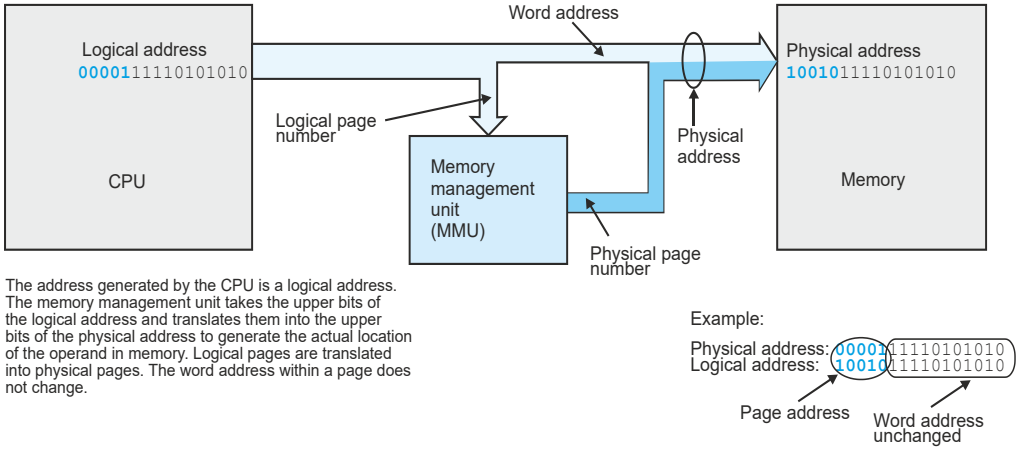
b) i. Virtual memory corresponds to the computer's view of the memory, which is different to the real physical memory which may consist of several different storage mechanisms (DRAM, magnetic disk, optical). The computer sees a large continuous memory with uniform properties (you could call this an abstract memory). The purpose of virtual memory is to free the programmer from worrying about actual memory and where to locate programs and data.
Moreover, the virtual memory can be larger than the computer's main memory (DRAM).

ii. Virtual memory is necessary for several reasons. First, the memory management unit (hardware) and operating system translate all addresses from the computer into the location of the actual data. This means that the programmer does not have to worry about the location of data; it is handled automatically. Virtual memory is also able to make some areas of memory protected (e.g., the operating system cannot be accessed by a user program). Similarly, virtual memory can enable data or code to be access by multiple users simultaneously without a clash. Second, virtual memory allows the user

to execute programs larger than the available physical high-speed DRAM by swapping data between the hard disk and DRAM (invisibly to the user).

iii. The figure below illustrates the concept of virtual memory. A logical address is generated by the CPU. This is the virtual address. This is fed to the memory management unit which is hardware (today it is in the CPU chip). This translates the logical address into the physical address of the data in the DRAM of the physical memory. During the address translation, the rights associated with the address can be checked (to ensure that the access is legal … for example, a page may be tagged as operating system only so that if a user program is running and it tries to access the operating system, an exception would be generated and the program terminated).

If the required physical page is not currently in DRAM, the translation cannot take place, The operating system intervenes by loading the required page from disk into DRAM and then completing the address translation. However, this process is time-consuming and can slow down the system if it happens too frequently.




**Examiners' Comments:**

*A3a) asked a generic question on What is an operating system? Being an open question, it gave the candidate the possibility of expanding on the topic. However, only a few candidates demonstrated knowledge of the purpose of the operating system and the facilities provided by it. The majority of the answers stated knowledge of computers in general.*

*In A3 b), the majority of the students gave unfocused answers on "Virtual computing" (VMware, etc) and "Cloud computing" instead of focusing on the concept of Virtual Memory.*

**A4.**

a) Some people use a computer's clock speed to judge the performance (speed) of a computer; for example, they may say that computer X is better than computer Y because computer X has a 3.5 GHz clock and computer Y has a 3.1 GHz clock. In general, it is regarded as wrong to use clock frequency to compare computers. Why is this?

**(10 marks)**

b) You are employed as a consultant to select a suitable high-performance computer for use by a small company. You make your selection and copy out the candidate computer's parameters (specification) for your client. Because your client is non-technical, you have to explain the relevance of some of the parameters. For the following specifications, write a paragraph that indicates the meaning, relevance, and importance of the specified parameter.

Your report should also explain why this specification corresponds to a high-performance computer (in 2019).

Workstation specifications:

- Processor:
  - CPU cores: 8
  - CPU threads: 16
- Memory: 64 GB, DDR4
- CPU clock: 4.7 GHz
- Storage device:
  - 2 TB SSD
  - 10 TB HDD
- Interface:
  - USB 3.0
  - USB 3.1 Type-C
- Extension slots: 4 x PCIe
- Network: Gigabit Ethernet

**(20 marks)**

**Answer Pointers:**

a) If two identical systems are running at different clock speeds, it is sometimes possible to say that the system with the higher clock speed is faster.

However, you cannot compare two different systems on the basis of clock speed. The time taken to perform a job is given by $N_i$ x C x $t_c$ where Ni is the number of instructions executed, C is the number of cycles per instruction on average, and $t_c$ is the clock cycle time.

As you can see, clock cycle time is only one factor. The architecture of the chip (instruction set) largely determines the value of $N_i$ and the implementation (organization) of the chip determines C. Different chips (even from the same manufacturer) have different internal organizations and architectures. Therefore, clock speed cannot be used to determine performance alone. Moreover, the performance of a computer is also strongly influenced by the memory cycle time, which is not related to CPU clock time.

b) Reading the specifications

CPU cores: 8

It is not possible to increase the speed of CPU clocks beyond approximately 4 GHz because of heating problems. CPU manufacturers have started putting multiple identical CPUs on a chip in order to increase performance. This requires that the program be converted into instruction streams that can be executed in parallel.

CPU threads:16

A thread is a stream of instructions that can be executed. An 8-core processor can execute 8 streams in parallel. However, it is possible to run multiple threads on one CPU by having two streams of instruction and switching execution from one stream to the other and then back. This does not require the CPU to be duplicated … only its working registers. This is called SMT (simultaneous multithreading) The advantage of this technique is that if one stream is held up (waiting for a resource like memory), the other stream can take over. This increased the usage of the computer. Note … in this case there are 8 cores and 16 threads which implies two threads per CPU

Memory: 64 GB, DDR4

The side of the main memory (immediate access memory) is 64 GB and is implemented by dynamic ram (DRAM). The DDR4 indicates the generation of the memory … DDR4 is the current fastest form of DDR (double data rate DRAM) and the 4 indicated fourth generation.

CPU clock: 4.7 Ghz

The CPU clock indicates the speed at which the CPU is clocked. Today, a value of 4.7 GHz would indicate a state-of-the-art processor.

2 TB SSD, 10TB HDD

These parameters indicate the secondary storage. SSD is semiconductor solid state storage and is replacing the magnetic HDD drive because it is far faster and more reliable. 2 TB of SSD would be found in a very high-performance machine and would be used to hold the operating system and frequently accessed data.

The 10TB HDD indicates a large magnetic disk drive. This is used for storing large volumes of data (e.g., video and images). It is far cheaper than SSD but very much slower.

Interface: USB 3.0, USB 3.1 Type-C

Computers provide several interfaces to external devices (e.g mouse, keyboard, audio, ethernet). The USB interface connects to a very wide range of devices from mouse to printer to hard disk drive).

The USB interface is an international standard. Many computers have a USB 2.0 interface which is relatively slow and provides a data rate of about 12 Mbs. The newer USB 3.0 is standard today and provides a faster data rate (USB 3.0 ports are compatible with older USB 2.0 connectors).

The newer USB 3.1 Type_C interface is a higher speed upgrade that provide 10 GBps data rates and can carry more power (for devices that use USB power). The non-computer end of the cable is also different to USB 3.0 because type C used a round

symmetrical connector that is now becoming standard in new mobile phones and tablets.

Extensions slots: 4 x PCIe

The PC allows you to plug in cards that provide extra functions not available on the computer itself. These functions can be anything from additional USB ports to high-quality sound cards to video (display) cards. The current standard for plug in cards is PCIe (peripheral connect interface express).

Network: Gigabit Ethernet

PCs are invariably connected to a network via a router. Typically, the connection may be via WiFi or Ethernet. Ethernet provides a fast secure data transmission system. It is secure because it does not rely on radio that can be picked up by anyone wishing to eavesdrop. The term gigabit Ethernet indicates a fast version of Ethernet. Data is transmitted at 1,000 million bits/s, but with overheads, the actual transmission rate is about 120 Mbytes/s.

**Examiners' Comments:**

*A4a) of the question assessed the candidates understanding of how a computer's performance can be evaluated, which the majority of the candidates were unable to explain. A4b) focused on the candidate's ability to evaluate the characteristics of a computer system based on the computer's specification including memory, processor, etc. The majority of the candidates understood each concept or knew the concept but provided speculative answers rather than informed ones.*

## Section B
**Answer 5 questions (out of 8) in Answer Book B. Each question carries 12 marks.**

**B5.**

Describe 2 advantages and 2 disadvantages of using biometric systems.

**(3 x 4 marks)**

**Answer Pointers:**

Advantages:

- Highly Secure
- More accurate
- Much easier to use
- Difficult to hack

Disadvantages:

- Require additional hardware
- Can't be updated remotely
- Difficult to secure if compromised
- Expensive to implement
- Unhygienic

**Examiners' Comments:**

*The question was about two advantages and two disadvantages of biometric systems. A large number of candidates suggested that a person's life maybe at risk due to these systems because they maybe be subject to criminal activity. Most candidates suggested that this system would be unreachable if the authorised person had an accident. Some students mixed it with biomedical systems and attempted to answer the question accordingly.*

**B6.**

Explain how cloud computing is more vulnerable to cyber-attacks compared to an isolated network?

**(12 marks)**

**Answer Pointers:**

- Reduced control on hardware
- Can be accessed from anywhere
- Data security is difficult
- Compliance issues in different countries (legal issues)

**Examiners' Comments:**

*A large number of candidates suggested that cloud computing was 'very easy' to hack into and it didn't have enough security compared to an isolated network. Only a small number of candidates suggested that cloud computing might have better or equivalent security measures.*

**B7.**

Describe the following cloud models with examples:

a. Software as a Service (SaaS)
b. Platform as a Service (PaaS)

**(6 x 2 marks)**

**Answer Pointers:**

Software as a Service

- Based on subscription of online software
- More suitable for small businesses
- Available everyone
- Device independent in most cases
- Easier to operate
- User doesn't need to worry about hardware and software updates
- Difficult to integrate with existing databases
- Examples: Microsoft 365, Google Apps, DropBox etc.

Platform as a Service

- Service provider provides all the infrastructure and operating system
- Built on virtualization technology
- User installs Applications and saves data on servers
- Easier to upgrade and include more hardware services
- Makes development of applications easier
- High availability
- Platform independent in most cases

**Examiners' Comments:**

*The majority of the candidates did not provide a suitable example or explanation of PAAS or SAAS however a high number of candidates explained the use of these services quite well.*

**B8.**

Describe 3 advantages and 3 disadvantages of embedded systems.

**(12 marks)**

**Answer Pointers:**

Advantages

- Faster to load
- Focused on limited tasks or operations
- Easy to manage
- Low cost
- Good performance
- Doesn't require upgrades over time

Disadvantages

- Rigid design
- Limited in processing abilities
- Difficult to update
- Limited hardware
- Troubleshooting is difficult

**Examiners' Comments:**

*Few candidates demonstrated an understanding of the role of embedded systems and how they operate. Some candidates confused it with software based embedded systems.*

**B9.**

Discuss the following security threats

a. DoS attacks
b. Viruses
c. Rouge Access Point

**(4 x 3 marks)**

**Answer Pointers:**

**DoS**

Denial of service attack floods the bandwidth of the target leaving it incapable of handling anymore requests from clients. Makes it inaccessible for intended users.

**Viruses**

A type of malicious programme that can alter how a computer operates. It is designed to spread from machine to machine. It attaches to a legitimate programme in order to execute. Can damage the system or compromise data security

**Rouge Access Point**

A wireless access point installed on a on a secure network without authorization. They can cause serious security risk due to non-compliance with the organizational policies. It can provide a wireless backdoor to cyber-attacks.

**Examiners' Comments:**

*The majority of candidates didn't answer correctly about DoS attacks or Rouge Access Points. Most candidates didn't attempt these two sections and only answered about viruses.*

**B10.**

Briefly explain each of the following concepts:

a. HDMI
b. 10BaseT
c. CSMA/CD

**(4 x 3 marks)**

**Answer Pointers:**

HDMI (High-Definition Multimedia Interface) is an interface to transmit uncompressed video and compressed data to and from a source. It is now used with computer monitors to obtain high quality images and audio for better user experience.

10BaseT
Based on IEEE 802.3 standard for Local Area Networks, 10BaseT is also called Twisted Pair Ethernet. It uses a twisted pair cable which can be used for up to 100 meters.10BaseT operates at 10mbps.

CSMA/CD
This is a MAC protocol based on a set of rules used to avoid collision between two devices connected on a network. It defines how two devices may respond if they try to use the same data channel simultaneously.

**Examiners' Comments:**

*A surprisingly large number of candidates suggested that CSMA/CD was a storage device. Only a handful of candidates attempted all 3 sections of the questions and answered them correctly.*

**B11.**

Discuss the following with at least one device example:

a. Full Duplex
b. Half Duplex

**(6 x 2 marks)**

**Answer Pointers:**

Full Duplex
A device that is capable of sending and receiving data simultaneously such as a switch or a router.
When a device is transmitting, it can receive data at the same time.

Half Duplex
A device that cannot send and receive data at the same time, e.g. a Hub

**Examiners' Comments:**

*Some candidates confused this question with printing duplex pages (double sided). Most candidates used a mobile phone and walkie talkie as examples rather than something relevant to network communications.*

**B12.**

Discuss 3 advantages of setting up a Local Area Network

**(4 x 3 marks)**

**Answer Pointers:**

- Sharing of files, folders and data
- Resource sharing e.g. printers and scanners
- Security
- Central disk space utilization
- Application may run on server, reducing resources required on local machines

**Examiners' Comments:**

*Most of the candidates described what a LAN was or the features of a LAN rather than 'Advantages' of setting up the LAN. This reduced the marks significantly as candidates would describe LAN as 'easy to setup' or 'cheap to run' which are not the 'benefits' of setting up a LAN. Many students described 'playing games' as the one of the advantages.*