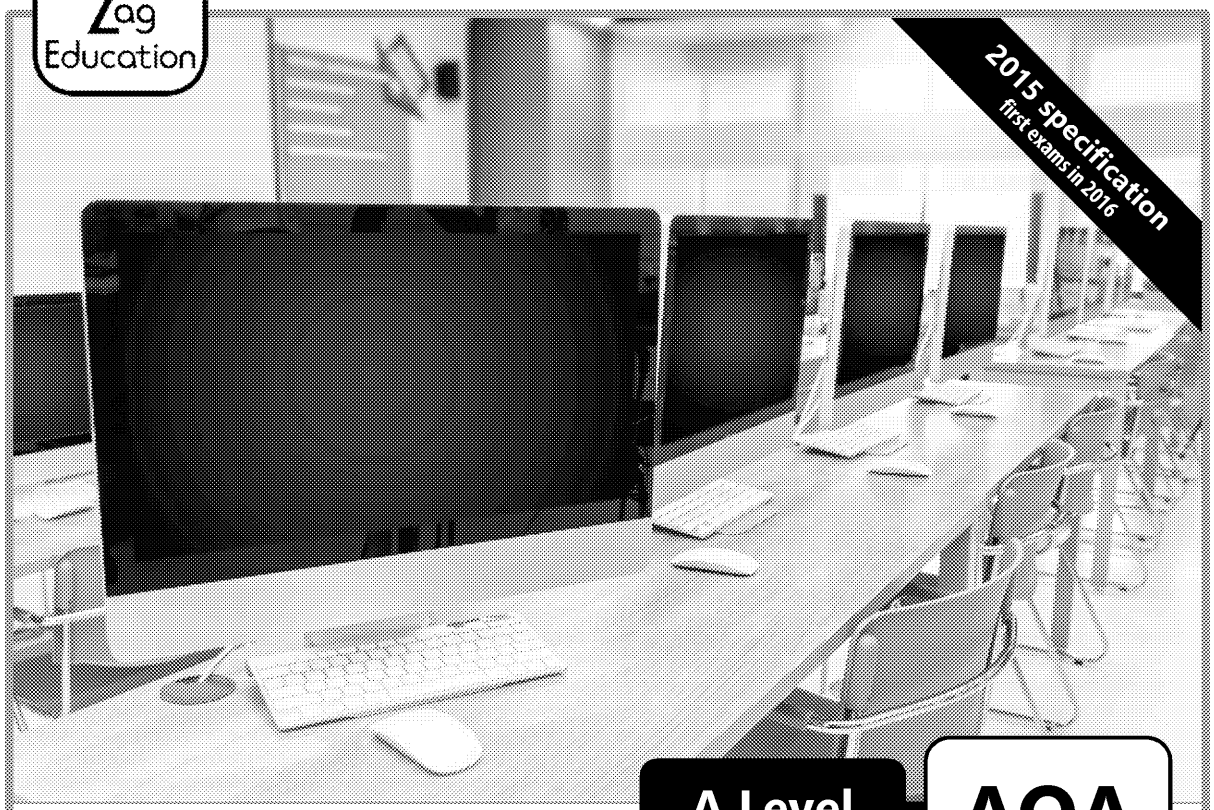
Zig Zag Education

Computer Science **A Level | AQA | 7517**



A Level **AQA**

Revision Guide

for A Level AQA Computer Science

Paper 2 – Topics 5-12

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POD 7760

Contents

TEACHER'S INTRODUCTION

This revision guide has been written to support the AQA A Level Computer Science specification (first teaching from September 2015, first exams in June 2017).

The essential theory required for the A Level Paper 2 specification is covered:

5. Data representation
6. Computer systems
7. Computer organisation and architecture
8. Consequences of uses of computing
9. Communication and networking
10. Fundamentals of databases
11. Big data
12. Fundamentals of functional programming

An equivalent resource is also available for the A Level AQA Paper 1 examination (topics 1–4).

Each section includes student notes, examples, diagrams and examination-style questions. Example answers to all of these questions can be found at the back of the resource. *Note that credit should also be given for any valid responses that are not explicitly included in this resource.* There is also a revision progress grid which students may find useful in the lead up to their exams.

November 2017

REVISION PROGRESS TRACKER: A LEV

Use the grid below to track your progress while revising for your exam. Start by enter
the top, and working down the grid, give a rating of between 1 (you really don't know i

This should help you to focus your revision on the areas that require it the most, so tha
comes up in the exam. Use the Notes column to record any actions.

Repeat this process until you feel you are confident enough in all areas and are ready f

Specification Topic	Confidence Level (1–5)				
	Date:	Date:	Date:	Date:	
5 – Fundamentals of data representation					
Number systems					
Number bases					
Decimal → binary					
Binary → decimal					
Decimal → hex					
Hex → decimal					
Binary → hex					
Bits and bytes					
Units of bytes					
Unsigned binary					
Unsigned binary arithmetic					
Signed binary using two's complement					
Fixed point binary					
Rounding errors					
Absolute and relative errors					
Range and precision					
Normalisation and floating point form					

Specification Topic	Confidence Level (1–5)				
	Date:	Date:	Date:	Date:	
Underflow and overflow					
ASCII and Unicode					
Error checking and correction					
Analogue ⇆ digital					
Bitmapped graphics					
Vector graphics					
Vector graphics versus bitmapped graphics					
Digital sound					
Musical Instrument Digital Interface					
Data compression					
Encryption					
Caesar cipher					
Vernam cipher					
6 – Fundamentals of computer systems					
Relationship between hardware and software					
Classification of software					
System software					
Role of an operating system					
Classification of programming languages					
Types of translator					
Logic gates					
Logic diagrams					

Specification Topic	Confidence Level (1–5)				
	Date:	Date:	Date:	Date:	
Half adder					
Full adder					
D-type flip flop					
Boolean algebra					
7 – Fundamentals of computer organisation and architecture					
Computer system components					
Von Neumann and Harvard architectures					
Stored program concept					
Parts of the CPU					
Fetch-execute cycle					
Processor instruction set					
Addressing modes					
Machine code and assembly language operations					
Interrupts					
Factors affecting processor performance					
External hardware devices					
Secondary storage devices					
8 – Consequences of uses of computing					
Awareness of current individual, social, legal and cultural risks					
Awareness of how digital technology can be used					
Responsibilities of computer scientists and engineers					
Challenges facing legislators in the digital age					

Specification Topic	Confidence Level (1–5)				
	Date:	Date:	Date:	Date:	
9 – Fundamentals of communication and networking					
Serial vs parallel transmission					
Synchronous vs asynchronous transmission					
Communication basic definitions					
Network topologies					
Peer-to-peer vs client–server					
Wireless networking					
The Internet					
Internet security					
TCP/IP					
Standard application layer protocols					
IP address structure					
Subnet masking					
IP standards					
Public and private IP addresses					
Dynamic host configuration protocol					
Network address translation					
Port forwarding					
Client–server model					
Thin- vs thick-client computing					

Specification Topic	Confidence Level (1–5)				
	Date	Date	Date	Date	
10 – Fundamentals of databases					
Conceptual data models					
Conceptual data models					
Entity relationship modelling					
Relational databases					
Database design and normalisation techniques					
Structured query language					
Client–server databases					
11 – Big data					
Volume/velocity/variety					
Distributed processing					
Functional programming					
Fact-based model					
Graph schema representation					
12 – Fundamentals of functional programming					
Function type					
First-class object					
Function application					
Partial function application					
Composition of functions					
Functional language programs					
Lists in functional programming					

TOPIC 5 – DATA REPRESENTAT

5.1 NUMBER SYSTEMS

Number System	Examples	Expla
Natural Numbers	$\mathbb{N}$ = {0,1,2,3,4, … }	$\mathbb{N}$ is the set of natural numbers used
Integer Numbers	$\mathbb{Z}$ = {… -2, -1, 0, 1, 2 … }	$\mathbb{Z}$ is the set of integer numbers, whic their negative inverses, as shown in t fractional part.
Rational Numbers	$\mathbb{Q}$ includes: 7/2, 8/1, 100/3, 1/2 , 16/4 …	$\mathbb{Q}$ is the set of numbers that can be w integers). Integers such as 7 are ration 7/1.
Irrational Numbers	$\sqrt{2}$, $\sqrt{3}$, π, $\sqrt{99}$	An irrational number cannot be written a all square roots are irrational; for examp
Real Numbers	$\mathbb{R}$ includes: 1, 12.41, $\sqrt{2}$, 0, 12/7, 1/8, 1.23423, 129.6	$\mathbb{R}$ is the set of real numbers, which i rational and irrational numbers; they Real numbers are used for **measurem** digits to the right of the decimal poin number measurement of 1.05 is more measurement of 1.
Ordinal Numbers	**S =** 1st 2nd 3rd / a b c	Ordinal numbers are used to describe ordered list. In the example, **S** is an o is the second object and **c** is the third

5.1 – Progress Check

1. Explain the difference between the natural number system (N) and the int

5.2 NUMBER BASES

Number base	Description
Decimal (base 10)	The decimal number system is based on the use of 10 digits: 0 10^2 or 100 | 10^1 or 10 | 10^0 or 1 3 | 5 | 8 — The numbe 10s and 1s a The subscript 10 can be used to indicate the number base use
Binary (base 2)	The binary number system is based on the use of 2 digits: 0 a 2^3 or 8 | 2^2 or 4 | 2^1 or 2 | 2^0 or 1 1 | 0 | 1 | 1 — The numbe 4s,2s and 1s So the binary number 1011 represents (1 x 8) + (0 x 4) + (1 x 2 The subscript 2 can be used to indicate the number base used
Hexadecimal (base 16)	The hexadecimal number system is based on the use of 16 di where A=10, B=11, C=12, D=13, E=14 and F=15 16^2 or 256 | 16^1 or 16 | 16^0 or 1 2 | E | 1 — The numbe 16s and 1s a So the hexadecimal number 2E1 represents (2 x 256) + (14 x 1 The subscript 16 can be used to indicate the number base use

Convert binary to decimal

To convert **binary 1011 0101 to decimal**, write the binary numbers into a table in the cor

128	64	32	16	8	4	2	
1	**0**	**1**	**1**	**0**	**1**	**0**	

Then add the decimal numbers where 1 is shown, so $1011\ 0101_2$ = 128 + 32 + 16 + 4 + 1 =

Convert decimal to binary

To convert **decimal 133 to binary**, create a table with the binary place values and use the

1. Find the largest place value that is less than or equal to 133.
   In this case, it is 128, so write 1 in row below 128.
2. Subtract 128 from 133 to obtain 5. Find the largest place value that is less than or
   In this case, it is 4, so write 1 in row below 4.
3. Subtract 4 from 5 to obtain 1. Find the largest place value that is less than or equa
   In this case, it is 1, so write 1 in row below 1.
4. Complete the process by adding 0 to all the blanks in the table.

128	64	32	16	8	4	2	
1	**0**	**0**	**0**	**0**	**1**	**0**	

Hexadecimal and binary

The **hexadecimal** number system (or **hex**) is based on 16 states. The table on the right car
used to convert between binary and hex.

Note that two-digit hexadecimal numbers are the equivalent of eight binary bits or one by
of data.

Convert binary to hexadecimal

Example:
To convert binary 11111011 into hexadecimal use the steps below:

1. Treat the 8-bit binary code as two hexadecimal nibbles: 1111 and 1011.
2. Use the table to convert 1111 to F and 1011 to B.
   So, $\mathbf{11111011_2}$ = $\mathbf{FB_{16}}$

Convert hexadecimal to binary

Example:
To convert hexadecimal A9 into binary use the steps below:

1. Convert the two hexadecimal nibbles separately using the table,
   so $A_{16} = 1010_2$ and $9_{16} = 1001_2$.
2. Join them together to form an 8-bit binary number.
   So, $\mathbf{A9_{16} = 10101001_2}$

Convert decimal to hexadecimal

Convert decimal to binary and then convert binary to hex.
Example – convert 189_{10} to hexadecimal

1. 189 decimal is converted to binary; therefore, $10111101_2 = 189_{10}$

128	64	32	16	8	4	2	1
1	0	1	1	1	1	0	1

2. Split the binary number into (4-bit) nibbles

8	4	2	1
1	0	1	1

8	4	2	1
1	1	0	1

3. Add up each nibble (value between 0 and 15) and convert into hex

   Giving $1011_2 = 11_{10} = B_{16}$ and $1101_2 = 13_{10} = D_{16}$

   Therefore, $189_{10} = 10111101_2 = BD_{16}$

Convert hexadecimal to decimal

Convert hexadecimal to binary and then convert binary to decimal.
Example – convert $5ED_{16}$ to decimal

1. $5ED_{16}$ is converted to binary so $010111101101_2 = 5ED_{16}$

5			
8	4	2	1
0	1	0	1

E			
8	4	2	1
1	1	1	0

D			
8	4	2	1
1	1	0	1

2. Convert the binary into decimal using the table below:

1024	512	256	128	64	32	16	8	4	2	1
1	0	1	1	1	1	0	1	1	0	1

3. 1024 + 256 + 128 + 64 + 32 + 8 + 4 + 1 = **1517_{10}**

5.2 – Progress Check

2. Convert binary 1110 0111 to decimal. (2 marks)
3. Convert decimal 101 to binary. (2 marks)
4. Convert hexadecimal 3FA to decimal. (2 marks)
5. Convert decimal 7012 to hexadecimal. (2 marks)
6. Convert binary 0011 1111 to hexadecimal. (2 marks)
7. Convert hexadecimal B7 to binary. (2 marks)

5.3 UNITS OF INFORMATION

Bits and bytes

Computer hardware is used to store and process data; hardware components use the binar
either 0 or 1.

Computer systems store data and program instructions using binary code, since digital cor
Therefore, all data that is input into the computer system needs to be converted into bina

Single binary numbers or digits are usually grouped together in computer systems to form

2^n different values can be represented with n bits as shown in the table below.

n	Bit Number	Bit Patterns	Different Bit Configuration for 2^n
1	2^1	2	0, 1
2	2^2	4	00, 01, 10, 11
3	2^3	8	000, 001, 010, 011, 100, 101, 110, 111
4	2^4	16	0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111

Binary Code is based on a number system that uses two digits, 0 and 1.

Bit is a single binary digit that can have the values 0 or 1.

Byte is a group of 8 bits. The maximum decimal number it can store is 255.

Nibble of 4 bit a byte'.

Units

The number of bytes can be described using binary prefixes representing powers of 2 or us
of 10.

Binary Powers			
Name	Symbol	Power	Description
kibi	KiB (kibibyte)	2^{10}	1 KiB = 2^{10}B
mebi	MiB (mebibyte)	2^{20}	1MiB =2^{20}B
gibi	GiB (gibibyte)	2^{30}	1GiB = 2^{30}B
tebi	TiB (tebibyte)	2^{40}	1TiB = 2^{40}B

D	
Name	Symbo
kilo	k (kiloby
mega	M (megab
giga	G (gigab
tera	T (teraby

5.3 – Progress Check

8. Define the term 'kibibyte'. (2 marks)

5.4 BINARY NUMBER SYSTEMS

Signed and unsigned binary

Signed binary numbers are encoded to include a positive or negative sign.

Unsigned binary numbers do NOT have a positive or negative sign so are useful for positive whole numbers only.

The advantage of using unsigned integers is that they can be used to store larger numbers than using signed integers.

An unsigned binary number has a minimum of zero and a maximum value of 2n-1, where n is the number of bits available; see the examples on the right.

Number of bit (n)	M
1	
2	
3	
4	
8	

Unsigned binary addition

Binary numbers can be added using the same techniques used to add denary numbers as s

Example: Add the binary numbers 0111 and 0101.

	0	1	1	1	1 + 1 = 2 so write 0 and carry 1
	0	1	0	1	1 + 0 + 1 = 10 binary so write 0 and carry 1
Sum	1	1	0	0	1 + 1 + 1 = 11 binary so write 1 and carry 1
Carried	1	1	1		0 + 0 + 1 = 1 binary so write 1

So 0111 + 0101 = 1100 binary

Unsigned binary multiplication

Binary numbers can be multiplied using the same techniques used to multiply denary numb example.

Example: Multiply binary numbers 0011011 by 101.

		0	0	0	1	1	0	1	1	Multiply 0011011
		0	0	0	0	0	1	0	1	By 101
			0	0	1	1	0	1	1	Step 1 multiply 00011011 by 1
	0	0	1	1	0	1	1			Step 2 multiply 00011011 by 1 a
		1	0	0	0	0	1	1	1	Binary addition three rows for fin
Carry			1	1	1	1				Use carry bits where necessary

So 00011011 x 00000101 = 10

Binary Multiplication Rules:

0 x 0 = 0
1 x 0 = 0
0 x 1 = 0
1 x 1 = 1 (there are no carry or borrow bits with binary multiplication)

5.4 – Progress Check

9. Add the following unsigned binary numbers: 00000101 and 11000100. (2
10. Multiply the following unsigned binary numbers: 00010101 and 000001

Signed binary using two's complement

Signed numbers are represented in computers using the **two's complement** method.

The most significant bit will indicate 1 for a negative number and 0 for a positive number. Two's complement subtraction is performed by simply adding a negative number.

Positive Numbers	Negativ
A positive number in two's complement form is the same as an unsigned integer except the most significant bit needs to be zero, representing a positive sign.	The two's complement is calculat 1. Inverting each of the binary 0's) 2. Adding 1 to this new numb
$0000\ 1111_2 = +15_{10}$	**$0000\ 1111_2 = 1111\ \ 0001_2 = -15$**

Subtraction using two's complement

Example: 15 – 12

$15_{10} = 0000\ 1111_2$ and
$12_{10} = 0000\ 1100_2$ which is (1111 0011) + 1 = **$1111\ 0100_2$** in two'

	0	0	0	0	1	1	1	1	15
	1	1	1	1	0	1	0	0	-12
Sum	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	15 – 12 = 3
Carry	1	1	1	1	1	-	-	-	

Signed binary using two's complement range

Binary	Decimal
0111 1111	+127
0000 1111	+15
0000 0001	+1
0000 0000	0
1111 1111	-1
1000 0001	-127
1000 0000	-128

The range of an unsigned Byte (8-bit

The range of a signed byte using tw
-128 to 127, as shown in the table c

**The range is – (2^{N-1}) to +(2^{N-1}-1) w
number of bits**

- In an 8-bit byte the first bit is the sign bit, so only 7 bits contain num
- The range of numbers for an 8-bit byte is – (**2^{8-1}**) to **+(2^{8-1}-1)** or **-12**
  - ➥ Highest positive number in two's complement 8-bit byte is **2^{N-1}-1**
  - ➥ Lowest negative number in two's complement 8-bit byte is – **2^{N-1}**

5.4 – Progress Check

11. Calculate 24 – 12 using two's complement. (2 marks)

Numbers with a fractional part

Fixed-point binary

Fixed-point binary is used to represent a fractional part of a number, where the binary poi

512	256	128	64	32	16	8	4	2	1	.	1/2	1/4	1/8	1
Integer Part										**Point**	**Fractional**			

Convert fixed-point binary to decimal

For example, to convert **1010000111.10010$_2$** into decimal, write the binary numbers into
shown below.

512	256	128	64	32	16	8	4	2	1	.	1/2	1/4
1	0	1	0	0	0	0	1	1	1	.	1	0

Then add the decimal numbers where 1 is shown:

1010000111. 10010$_2$ = 512 +128 + 4 + 2 + 1 + 0.5 + 0.0625 = **775.5625**

Alternatively: 512 +128 + 4+ 2 + 1 + $\frac{1}{2}$ + $\frac{1}{16}$ = **775$\frac{9}{16}$**

Convert decimal to fixed-point binary

To convert **decimal 130.25 to binary**, create a table with the binary place values and use

1. Find the largest place value that is less than or equal to 130.25.
   In this case, it is 128, so write 1 in row below 128.
2. Subtract 128 from 130.25 to obtain 2.25. Find the largest place value that is less
   In this case, it is 2, so write 1 in row below 2.
3. Subtract 2 from 2.25 to obtain 0.25. Find the largest place value that is less than
   In this case, it is 0.25, so write 1 in row below 0.25.
4. Complete the process by adding 0 to all the blanks in the table.

512	256	128	64	32	16	8	4	2	1	.	1/2	1/4	1/
0	0	1	0	0	0	0	0	1	0	.	0	1	0

5.4 – Progress Check

12. Convert fixed-point binary number 1001111100.10100 into decimal. (3

Rounding errors

Rounding replaces a number with an approximate value using fewer digits. In the decimal s
rules:

- If the value of the last digit to be represented is greater than or equal to 5, then incre
- If the value of the last digit to be represented is less than 5, then the previous digit re

For example, 34.567 can be rounded to two decimal digits giving 34.57; note that the last d
process.

Rounding errors
The use of rounding creates an error between the original number and the rounded off nu

In example above, rounding error = 34.567 – 34.57 giving an error of -0.003

In many cases, when converting from decimal to binary there are rounding errors, as decimal f
exactly as binary fractions. In this case, rounding errors can be minimised by increasing the nu

Absolute and relative errors

Absolute error is the difference between the theoretical exact value calculated with no errors present and the processed computed value to be stored.	There are often errors in the value when compared to the theoretical v These errors are caused by factors followed by truncation, and finally
Relative error is the value of the absolute error divided by the theoretical exact value with no errors present.	The relative error gives a less misl the result as it takes into account t In this case, the error is compared

The formulae used to calcuate these errors are:

Absolute error = | exact value – computed value | Note
Relative error = | exact value – computed value | / exact value = Absolute error /

Examples

1 – Find absolute and relative errors for a computed value of 0.02 and an exact value o
Absolute error = | exact value – computed value | = | 0.017 – 0.02 | = 0.003
Relative error = Absolute error / exact value = 0.003 / 0.017 = 0.17647

2 – Truncation is used giving an exact value of 7.278 with computed value of 7.27 Find
Absolute error = | exact value – computed value | = | 7.278 – 7.27 | = 0.008
Relative error = Absolute error / exact value = 0.007 / 7.278 = 0.000961

Range and precision

Precision is associated with word length and the maximum number of significant dig

The mantissa is part of the floating point word which represents the significant digits
have fewer significant digits included in the mantissa than a comparable fixed point v

Range is the set of all numbers that can be represented using a specific number syst

The numbers available from an 8-bit two's complement integer representation are fr
This gives a range of 255, based on the difference between the smallest and largest n

Floating point is a real data type where the binary point can move within a number.

Floating point numbers can represent a wider range of numbers than a comparable f
mainly used where a wide range of values need to be processed.

Fixed point is a real data type is where a number has a fixed number of digits either

Fixed point numbers include the following properties:

- Fixed point binary numbers have more precision than floating point numbers but
- In fixed point operations the absolute error will be constant
- Faster speed of operation for fixed point operations when used on certain hardw

Fixed point operation is primarily used in applications where a high level of precision

5.4 – Progress Check

13. Calculate the rounding error when 72.465 is rounded to four significant

14. (a) Explain the term 'absolute error'. (1 mark)
    (b) Find absolute and relative errors for a computed value of 0.082 a (2 marks)

15. (a) Define the terms 'range' and 'precision'. (2 marks)
    (b) Compare range and precision for floating point and fixed point da

Normalised floating point representation

Decimal numbers can be represented in standard form.

For example: 2724.5 can be represented as 2.7245×10^3

So the mantissa is 2.7245

And the exponent is 10^3, which indicates that the decimal point has floated 3 places to the left.

The same floating point standard can be adopted in binary arithmetic; in the examples below a 16-bit floating point number consists of a 10-bit mantissa and a 6-bit exponent.

Normalised floating point position is fixed in a standa can float to reflect differen

Mantissa is the part of the the significant digits within

Exponent is the power tha raised.

10-bit mantissa – binary point is after the most significant bit

The mantissa and exponent binary data is stored in two's complement form so that positiv represented as well as positive and negative exponents.

Exponent Value	-32	16	8	4	2

Mantissa Values	-1	1/2	1/4	1/8	1/16	1/32	1/64

Example – positive mantissa and positive exponent

Convert floating point number 0110001000.000011 to denary:

Exponent 000011= 3 in denary
Mantissa is 0.110001000
The binary point needs to be moved three places to the right, giving 0110.00100
0110 is 6 in denary
.001 is 1/8 in denary

Therefore, binary number 0110001000.000011 is 6.125 in denary

Example – positive mantissa and negative exponent

Convert floating point number 0110000000.111101 to denary:
Exponent 111101
Two's complement of exponent is 000011 = -3 in denary
Mantissa is 0.110000000
The binary point needs to be moved three places to the left, giving 0.000110000
0.00011 is 1/16 + 1/32 = 3/32 or 0.09375 in denary

Therefore binary number 0110000000.111101 is 0.09375 in denary

Example – negative mantissa and negative exponent

Convert floating point number 1110000000.111110 to denary:
Exponent 111110
Two's complement of exponent is 000010 = -2 in denary
Mantissa is 1110000000
Two's complement of mantissa is -0010000000
The binary point needs to be moved two places to the left, giving -0.000100000
-0.000100000 = - 1/16 or -0.0625

Therefore, binary number 1110000000.111110 is -0.0625 in denary

Example – negative mantissa and positive exponent

Convert floating point number 1110000000.000011 to denary:
Exponent 000011= 3 in denary
Mantissa is 1110000000
Two's complement of mantissa is -0010000000
The binary point needs to be moved three places to the right, giving -0010.0000
-0010.000000 = - 2

Therefore, binary number 1110000000.000011 is -2 in denary

Underflow and overflow

If the result of a calculation is smaller than the smallest number that can be represented by the system, then an underflow will occur and the result will be stored as zero; dividing very small numbers can cause underflow.	**Under** is too of bit
If the result of a calculation is too large a value to be represented by the system, then an overflow will occur; this can cause serious problems and is most likely to occur when multiplying two large numbers. Double precision registers can be used to minimise the occurrence of overflow.	**Overf** too la bits a

5.4 – Progress Check

16. Convert the floating point number 0110110000 111001 that consists of a exponent into denary. (4 marks)
17. Compare the terms 'underflow' and 'overflow'. (2 marks)

5.5 INFORMATION CODING SYSTEMS

Character encoding

When a character is pressed on the keyboard, a binary code for that character is input into the computer; characters can be encoded into either ASCII or Unicode.

There is a need to differentiate between the encoded decimal digits and their pure binary numbers; this is shown in the ASCII table below, where the ASCII code for the decimal 1 is represented by the pure binary number representing 49.

ASCII is a seven-bit character set which offers 128 different characters. Some of these characters are used for controlling peripherals.

Every character on the keyboard has an ASCII code and lower-case letters have different codes to upper-case letters.

The main limitation with ASCII is that it does not have enough characters to cope with languages that have large character sets.

ASCII	Decimal	Binary
1	049	011 0001
2	050	011 0010
3	051	0110011
4	052	0110100
5	053	0110101
6	054	0110110
7	055	0111111
8	056	0111000
9	057	0111001
:	058	0111010
;	059	0111011
<	060	0111100

Unicode is
65,536 dif
characters

Unicode has be
by all major we

Unic
0000 0
0000 0
0000 0
0000 0
0000 0

Note that ASCI
Unicode uses m
per character; A

Error checking and correction

Parity checking

Error checking is frequently carried out on data that is transmitted and parity is a simple m
data that has been received. Parity checking is only able to detect an odd number of error
detected.

Even parity is where the number of 1s is counted and if the number of 1s is odd then

In the example below the 7-Bit ASCII code for Q is 1010001, which is an odd number of 1

Parity Bit	ASCII Code for Q				
1	1	0	1	0	0

Odd parity is where the numbers of 1s is counted and if the number of 1s is even ther

In the example below the 7-Bit ASCII code for S is 1010011, which is an even number of 1

Parity Bit	ASCII Code for S				
1	1	0	1	0	0

Majority vote

The parity bit approach can only detect errors in data transmission, but the majority vote c
correction.

With **majority voting**, each bit is sent three times and checked each time. If it is the sa
different on one occasion there is an error, in which case the majority of two will dete

In the example shown data sent is 01100, each bit will be transmitted three times.

Data transmitted will be	000	111	
With interference errors data received is	100	101	
Each triplet is then checked and majority accepted	000	111	

Main disadvantage of majority vote correction method is three times the volume of data n

Checksums

A checksum is an error detection method where the number of bits transmitted in a m
compared with a count of the data received to check the integrity of the data transm

Check digits

A **check digit** is added to binary data to check that the data is accurate; this is an appr
bar code printed on an item of shopping has been correctly entered into a computer.

The check digit is a single digit that is calculated using a mathematical algorithm and inse

A typical method used is based on modulo-11 as shown in the example below:

1	2	8	0	2	4	Original number
7	6	5	4	3	2	Weighting – each of the origina
7	12	40	0	6	8	Multiply weights and add them t
73 divided by 11 = 6 remainder 7						Divide total by 11 since it is a n
11 – 7 = 4						Subtract the remainder from 11
1280244						Original number with check digi The computer system will perfo read in and compare the answe then the data was entered corre

5.5 – Progress Check

18. Compare the use of ASCII and Unicode systems for character encoding.
19. Explain, with an example, even parity for error detection. (2 marks)

5.6 REPRESENTING IMAGES, SOUND AND OTHER DATA

Bit patterns

ⓘ A **bit pattern** is an arrangement of binary digits arranged in a sequence; they can be u
Unicode) as well as images (bitmaps and vector graphics), video and sound.

Analogue and digital

	Analogue	
Data and Signals	Analogue data and signals vary in a continuous way. For example, the output from a microphone into a tape recorder is an analogue signal that varies as a function of the pressure of the sound.	Digital data and sig discontinuous binar For example, a soun and stored as a serie

Conversion between analogue and digital data

It is necessary to convert analogue signals using an **analogue-to-digital converter** (ADC) i be input and processed in a computer. The output from a computer may need to be conver **digital-to-analogue converter** (DAC) to interface with an analogue device.

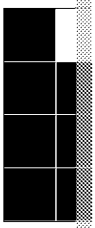
Analogue to Digital Converter (ADC)	Digital to A
Analogue to digital converters (ADCs) receive signals input via an analogue sensor in the form of voltage waveforms which are converted into a digital format so they can be read into a computer.	Digital to analogue cor signal into a continuou commonly, this is to an to drive audio speakers

Bitmapped graphics

Digital images are composed of a series of **pixels** or dots, so a pixel is the smallest element in a digital image.

Images are represented in digital or binary form to be stored or used on a computer. The black and white image of a staircase is shown on the right, where for each pixel 1 = black and 0 = white.

Colour can be shown in digital images by using more bits per pixel.



ⓘ **Colour depth** is the number of bits used for each pixel, where 1 bit is black and white and 8 bits will give 256 colours.

Bits
8 (
16 (

ⓘ **Image resolution** is calculated using the pixel dimensions (height x width).

ⓘ **Display Resolution** is the number of dots per inch (DPI).
More dots per inch give a better image resolution.

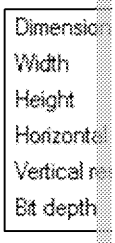
ⓘ **Metadata** is 'data about data'; metadata in an image file provides details of properties such as the image dimensions and colour depth.

Image metadata and storage requirements

Metadata is used by the computer to help it interpret an image file, since all data is basically stored in binary format.

The image on the right shows some typical metadata properties for a digital image.

Image storage requirements are calculated using he following formula:
Storage = width (pixels) x height (pixels) x colour depth (bits per pixel)

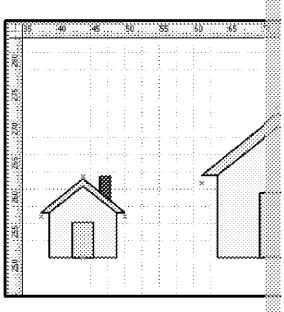


Vector graphics

Vector graphics are produced in graphics packages and are created using a series of objects and their coordinates.

The diagram on the right is an object (the home icon), and it has been copied twice and rescaled.

The size of the objects can be made larger, but the image quality of each object remains the same and requires the same storage. A vector graphic can consist of many individual objects that can be edited independently.



Objects are made up of a series of geometric shapes and a set of coordinates (reference po
geometric shapes can be constructed using mathematical formulae to create objects based

It is possible to edit objects with the image individually; the changes that can be made inc

- Shape of the object
- Colour of lines or fill in an object
- Size of object and thickness of lines
- Reference position, by dragging the object to a new position in the editor

Vector graphics can be used to create simple shapes that can be copied to create more co

Vector graphics versus bitmapped graphics

There are many differences and uses of bitmapped graphics and vector graphics, as tabula

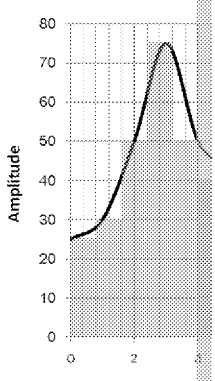
Bitmapped graphics	Ve
Bitmapped images are used in digital photography and website applications, where they provide realistic images.	Vector graphics are used in precise technical drawings. and logos.
Bitmap images store individual pixels and, therefore, take more storage space and memory than vector images.	Vector graphics are made u taking up less storage spac images.
Where bitmapped images are resized, the image quality is degraded and can appear fuzzy.	Vector graphics can be resc
Bitmap images use less processing power than vector graphics.	Vector graphics use more p

Digital representation of sound

When sound is input into a computer, it will be converted into a digital data file using an ADC.

In the graph on the right, the analogue sound input is sampled at regular intervals; the converted digital sound is shown superimposed on the analogue wave.

The digital sound is only approximately the same shape as the analogue wave; the sound quality can be improved by increasing the sample rate.



ⓘ **Sampling rate** (measured in Hz) is the number of samples taken per second from the analogue input to create a digital signal.

ⓘ **Nyquist's theorem** indicates that the sound must be sampled at twice the highest analogue input frequency to create an accurate representation of the original input waveform.

ⓘ **Sampling reso** number of bits

Sound sample size calculation

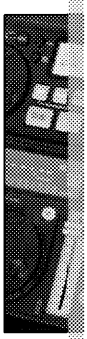
Example: Given that: Sample frequency = 4000 Hz, Sample resolution = 16 bits (2 bytes How much disk space would a 120-second sound recording require?

File size (bytes) = sample frequency (Hz) x sample resolution (bytes) x lengt
= 4000 x 2 x 120 = 960,000 bytes

Musical Instrument Digital Interface (MIDI)

ⓘ **MIDI** (Musical Instrument Digital Interface) is a protocol that is used to synthesise mu recording and playing back music input from keyboard, voice and other musical instru

MIDI makes use of **event messages** that are used to control musical parameters such as notation and pitch and volume, and to synchronise the rhythm between a range of other devices.



The main advantages of using a MIDI system are:

- Music data that has been loaded onto the computer can be arranged and manipulated in many different ways.
- A musician or music producer can make use of overlays to create a whole band sound.
- It is straightforward to create a musical score from the edited music.

5.6 – Progress Check

20. Describe the functions of an analogue to digital converter and a digita

21. Define the following digital image terms:
    (a) Colour depth (2 marks) (b) Resolution (2 marks)

22. Calculate the memory used in kilobytes for a digital photographic ima pixels high, with colour depth 24 bpp (bits per pixel) where 1 byte = 8

23. Define the following digital sound terms:
    (a) Sampling rate (1 mark) (b) Sampling resolution (1 mark

24. (a) Describe one advantage of using vector graphics. (1 mark)
    (b) Describe one advantage of using bitmapped graphics. (1 mark)

Data compression

Data compression is important in data transmission via the Internet, as compressed data creates smaller files so that they can be transmitted faster and require less storage space on the computer system.

Data com
downloa
also be r

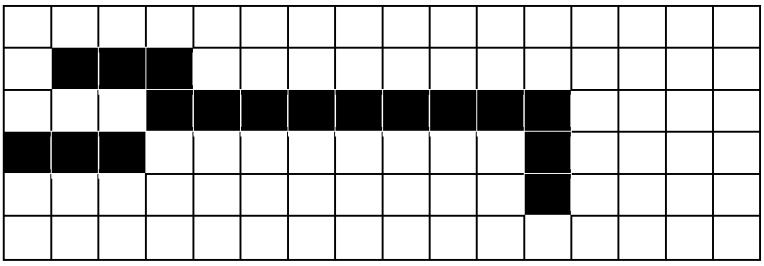
Lossy and lossless compression

Compression method	Advantages a
Lossless compression techniques allow the original data to be perfectly reconstructed, resulting in no loss of data.	An image can be compressed to low resolut also be needed in a higher resolution in a p
	A program may be compressed to be downl need to be expanded to an exact copy of th
	A text document might be compressed into transmission using email. Again the docume exact copy of the original to ensure that it c
Lossy compression techniques result in a loss of data, so the original data cannot be perfectly reconstructed.	A copy of an image might be compressed to website, but there is no need to expand bac
	In sound files unnecessary data can be redu output quality is acceptable for the user.

Run-length encoding

Run-length encoding (RLE) is a form of lossless compression where a sequence that c replaced by a single value of that data with a count of the number of times it occurs.

The black and white bitmap image (16 x 6 pixels) shown below can be used to demonstrate



This image can be written in the raw format below where a white pixel = 0 and a black pix

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Run-length encoding can be used to represent the data in the following compressed form.

Row	RLE code	Description
1	16,0	16 '0' elements
2	1,0 3,1 12,0	1 '0', 3 '1' and 12 '0' elements
3	3,0 9,1 4, 0	3 '0', 9 '1' and 4 '0' elements
4	3,1 8,0 1,1 4,0	3 '1', 8 '0', 1 '1' and 4 '0' elements
5	11,0 1,1 4,0	11 '0', 1 '1' and 4 '0' elements
6	16,0	16 '0' elements

The RLE
bitmap fr
bitmap in
that the i

This is a
reformed

Dictionary-based compression

The **dictionary-based** compression method (sometimes known as a substitution technique) contains encoded bit strings that contain fewer bits than the original code, so:

- Variable-length strings of symbols are encoded as single symbols or tokens.
- The token is used as the index for the look-up table or dictionary.
- Compression takes place where the tokens are smaller than the original variable

This is a lossless compression method, as the original file can be created by using the dict where large amounts of data can be referenced by a simple token, such as a post code or a

The general idea behind dictionary encoding is straightforward. If a large amount of text is number of pages, a dictionary of data – such as words and phrases that are used in the bo element of data has its own reference.

When a specific word or phrase is used on a page, it can be substituted for a compressed c Dictionary-based compression algorithms encode variable-length strings of symbols as sin

The dictionary can be coded as a simple look-up table where each word in the dictionary c indicates the page number and Y gives the number of that word on the page. In a typical d page is A, so it has a reference of 1/1.

Encryption

Encryption is used to make stored data more secure from hackers, by making it unread key to decrypt or decode it. This method is commonly used to protect data transmitted

Encryption operates by modifying plain text using an encryption algorithm; this takes plac which stipulates how the message will be encoded. An authorised user is able to decode t decryption key based on a decryption algorithm.

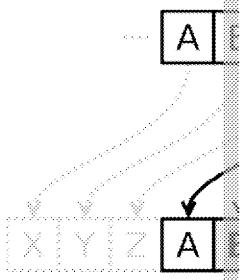
Caesar cipher

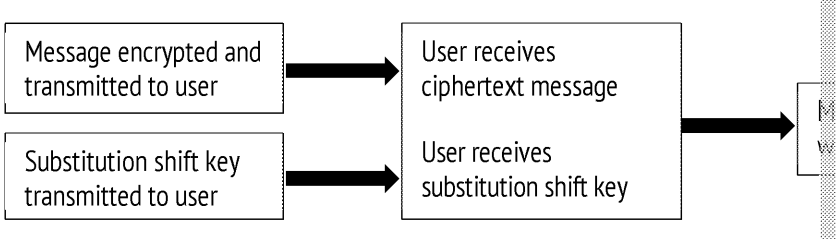
The Caesar cipher is a commonly used and simple substitution cipher; using this technique each of the plaintext letters in a message is replaced by a different letter of the alphabet a fixed position from the original letter.

The cipher shown on the right is replacing each letter with a different letter using a left shift of 3; therefore, E is represented by B, F is represented by C and so on.

Therefore, the ciphertext for the message will substitute 'B' for each 'E' that appears in the plaintext. Messages are transmitted using the approach shown in the diagram below.

A **cipher** algorithm creating ciphertex and turning it back





The table below can be used to convert between the ciphertext and the plaintext for a lef
link between E and B is highlighted.

Plain:	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Cipher:	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P

Encrypt using the table above and replace each letter of the plain text message with the le

Ciphertext: **ZLJMRQBO PZFBKZB**

The message is decrypted by using the table to reverse the process, so that each letter of
letter above in the plain text line.

Plaintext: **COMPUTER SCIENCE**

The Caesar is easily cracked as there are only shifts between 1 and 25 so each can be tried
and then the shift can be applied to all the text to crack the cipher.

Vernam cipher

The Vernam cipher or 'one-time pad cipher', is a digital data stream cipher that is combined with a same length random stream of date to create the ciphertext, based on the Boolean exclusive OR function.

The truth table for the Boolean **Exclusive OR** function is shown on the right.

Example:
To encrypt the ASCII code for 12 using the Vernam cipher use the following steps:

Plaintext – ASCII (1 and 2)	0110001 0110010	14 characters
Random key chosen	1010101 0111100	Any random key of the same length
Ciphertext	1100100 0001110	Created from Exclusive OR Plaintext

Decryption is the reverse of this process as shown in the table below:

Ciphertext	1100100 0001110	14 characters
Random key	1010101 0111100	Use the same random key chosen fo
Plaintext – ASCII (1 and 2)	0110001 0110010	Decrypted from Exclusive OR Ciphe

The Vernam cipher is known as a one-time pad as the key must only be used once.

If the key is randomly chosen and used only once, unlike other ciphers, the resultant ciphe
matter how much time is spent trying to crack the code, so the Vernam cipher is a perfect

Computational security is a term used to indicate the effectiveness of a cipher.

As stated, the Vernam cipher is considered to be 100% mathematically secure.

In theory, every other cipher can be broken given sufficient ciphertext and time; encryption c
Caesar cipher) can be cracked by the recognition of patterns or by the dictionary process of i
text.

5.6 – Progress Check

25. Explain the difference between lossless and lossy compression. (4 marks)
26. Define the terms 'encryption' and 'cryptography'. (2 marks)
27. Briefly describe the Caesar cipher algorithm and decrypt the ciphertext:
    CU EQORWVGT UEKGPEG
    that has been encrypted with a Caesar cipher and a right shift of two. (6

6.1 HARDWARE AND SOFTWARE

Relationship between hardware and software

A computer system operates with hardware and software to create a functional solution.

Computer hardware is the physical part of a computer, which includes digital circuitry, as distinguished from the applications software that is executed using the hardware. The processing hardware is necessary to gain a useable output from the system.

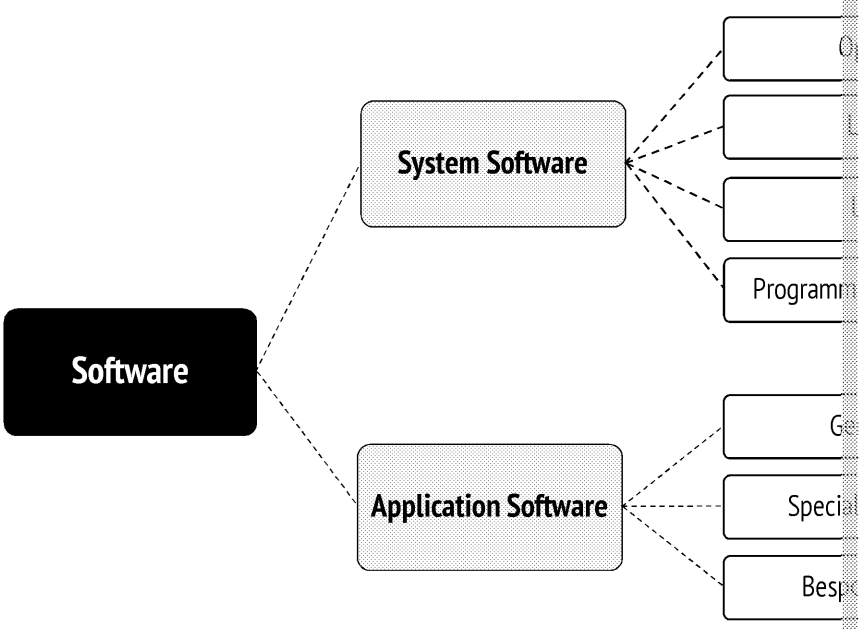
Software can be classified as systems software and applications software – the diagram below shows the types of software included in each.

Software refer
instructions th

Hardware refe
computer syst

Systems softw
operate the ha

Applications s
user-related ta
Payroll (SA) or



Systems software

Software	Main Features
Operating System (OS)	The operating system (OS) is the software that controls the hardware a hardware by creating a platform to run application software. Hiding the complexity of the hardware with a Windows-based operati machine that has a user-friendly interface and operates in the same m manufacturer of the computer system. Main functions include: resource management and the creation of use conflicts where a resource, such as a printer, is requested by more tha time; the OS manages these resource requests in a systematic way. O be managed are processor allocation, peripheral hardware devices, m
Library Programs	Library programs are pre-written software that is stored in compiled f programmer within one or more programs. Library functions are wide interacting with peripherals such as printers. A typical example of a library function from the mathematics library calculate a square root.

Software	Main Features
Utility Programs	Utility programs are a range of systems software that is designed to h optimise the system. Main functions include: disk formatting, file com firewall, memory testing and anti-virus protection.
Programming Language Translators	Programming language translators are used to translate a program in different programming language and to maintain the functionality of using one of the following software programs: 1. Assembler – used for assembly language programs 2. Compiler – used for program languages such as: C++, Visual B 3. Interpreter – used for program languages such as: some versi

6.2 CLASSIFICATION OF PROGRAMMING LANGUAGES

Programming languages

Programming languages can be classified as listed below.

Language	Sample Code
Low-level (1st Generation) Machine Code	Load data into register 8, taken from memory cell 68 where location c are listed in register 3: Operation: 35 / 100011 — Register Operations: 3 / 00011, 8 / 01000 — Memory Address: 68 / 00000 00001 00100

Low-level (2nd Generation) Assembly Language	`SET r1, 12 ; set register 1 to 12`
	`STORE A, r1 ; store register 1 contents into variab`
	`LOAD r2, A ; load variable A into register 2`
	`STORE B, r2 ; store register 2 contents into variab`
	The ';' symbol is used to add comments

High-level	`IF (ExamScore > 55) THEN`
	`  ExamGrade = "Pass"`
	`ELSE`
	`  ExamGrade = "Fail"`
	`END IF`

	Sample to create database table in SQL:
	`CREATE TABLE Subjects (`
	`Subject_Id int NOT NULL AUTO_INCREMENT,`
	`Student _Id int,`
	`Subject varchar(20),`
	`Subject_Mark int,`
	`FOREIGN KEY (Student_Id) REFERENCES Students (Student _Id) )`

Imperative Languages

High-level languages include imperative languages, which is where the program statemen sequence or order as defined by the programmer. These languages, sometimes known as p subroutines and functions to aid readability and hence maintainability.

Low-level languages are imperative as all instructions are executed in a set sequence; eac level is translated into numerous machine code statements prior to the execution of the co

Machine-code and assembly languages compared to high-leve	
Advantages	Programming in low-level code can create faster and more efficient performance level of the created code; with high-level programmin create optimised code.
	Low-level language code is memory efficient due to the lack of abst high level languages.
Disadvantages	It is difficult to learn to program in low-level languages whereas hi and training options.
	High-level code can be self-documenting which makes it more unde maintenance and debugging.
	Machine-code and assembly programs are specific to a limited rang code can be compiled to run on a wide range of processors.

6.2 – Progress Check

1. Explain the difference between hardware and software. (4 marks)
2. Describe the following:
   (a) Machine code (2 marks) (b) Assembly language (2 marks)
3. Describe the advantages and disadvantages of machine code and assem high-level languages. (6 marks)

6.3 TYPES OF PROGRAM TRANSLATOR

Types of program translator

Source code is the language instructions that have been written by the computer programmer. The computer cannot execute the source code directly.	➡	**Object Code** (or ex source code using instructions that c

Programming languages can be classified as listed below.

Translator	Characteristics	
Assemblers	The source code is written in assembly language, which is a series of mn machine operational codes; assembly code is the most difficult language of expertise to write and debug it. The assembler translates this source code into machine code that the co	
	Advantage: it is an efficient low-level language that can be translated quickly as it has a one-to-one relationship with machine code.	**Disadvantage:** programming t
Compilers	The source code created by the programmer is not understandable by the called a compiler converts the source code to object code, which the com converted to match the target computer that will run the software.	

	Advantage: an executable file is produced which runs without the need of the source code; this makes the source code more secure as it does not need to be distributed to the customer.	**Disadvantages**: a long time to c… code need to b… can be produce… necessary to co… code.

Translator	Characteristics	
Intermediate Language	Some compilers create a final output in an intermediate language, such a… run on a virtual machine (VM) rather than on a central processing unit (CP… program is portable and not machine dependent when in VM format. A bytecode interpreter is used to translate the VM code into machine lan… the code is executed. Although the bytecode interpretation takes time, th… machine is more efficient than if the source code was compiled directly; t… and Java.	
Interpreters	Interpreter software normally executes the source code directly, it is tran… need to compile the program. Interpreted software runs more slowly than compiled software as each st… before it is executed.	
	Advantage: during development the programmer might make frequent changes, which can be tested without going through the time-consuming process of compiling and linking for each change.	**Disadvantage:** t… the target com… machine code a… Additionally, th… customer and t… takes longer th…

6.3 – Progress Check

4. Define the terms 'source code' and 'object code'. (4 marks)
5. Describe the advantages and disadvantages of using an assembler as a tr…
6. Describe the advantages and disadvantages of using a compiler as a trans…
7. Describe the advantages and disadvantages of using an interpreter as a t…

6.4 LOGIC GATES

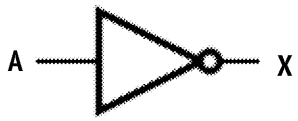
Logic gates

Binary numbers are stored in a computer system as different voltage levels where 0 is low voltage and 1 is high voltage.

The electronic circuits used in computers can be wired together to form logical operations; these circuits are based on logic gates.

NOT

The output is the inverse (opposite) of the input.



AND

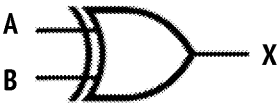
Two or more inputs where the output is true if all inputs are true.

OR

Two or more inputs where the output is true if either or both inputs are true.

XOR

Two or more inputs where the output is true ONLY if one input is exclusively true.



NAND

Two or more inputs where the output is false when all inputs are true.

NOR

Two or more inputs where the output is true when all inputs are false.

Note: NAND and NOR logic gates are not examinable at AS Level.

Half adder logic

Half adder circuit carries out addition on two numbers (A and B) only.

Details are shown in the truth table below.

Inputs		Outputs	
A	**B**	**C** (Carry)	**S** (Sum)
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

A
B

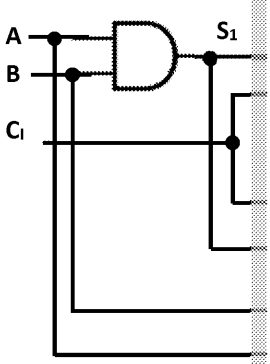
Full adder logic

Full adder circuit carries out addition on two numbers (A and B) and a carry bit.

A series of full adders can be used to add two binary numbers, as the carry bit is available at each stage of the calculation.

Details are shown in the truth table below.

Inputs			Outputs		
A	**B**	C_{IN}	C_{OUT}	S_1	**S**
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	0	1	1
0	1	1	1	1	0
1	0	0	0	1	1
1	0	1	1	1	0
1	1	0	1	0	0
1	1	1	1	0	1



The logic gates create the Boolean equations:

S_1 = A XOR B
S (sum) = S_1 XOR
C (carry) = (S_1 AN

6.4 – Progress Check

8. (a) List the outputs from a half adder when A = 1 and B = 1. (1 mark)
   (b) List the outputs from a half adder when A = 0 and B = 1. (1 mark)

9. (a) List the outputs from a full adder when A = 1, B = 1 and C=1. (1 ma
   (b) List the outputs from a full adder when A = 1, B = 0 and C=1. (1 ma

D-type flip flop logic

A flip flop is an electronic circuit that has two stable states and can be used as a memory device to store one bit of data.

A D-type flip flop changes state with each clock pulse, so data is delayed by one clock pulse.

The D-type flip flop symbol is shown on the right.

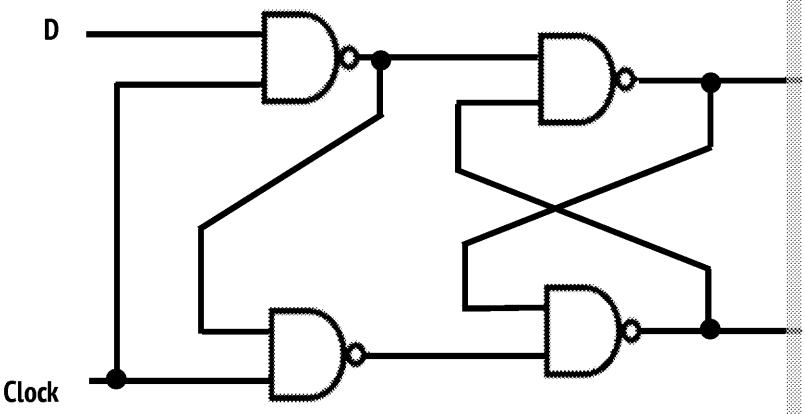
- It has a data input D and a clock input.
- The outputs are Q (data delayed by one clock pulse) and the inverse of Q.

A symbol f

D

Clock

D-type flip flops or delay flip flops can be wired from four NAND gates, a



Clock	D	Q
0	X	$Q_{PREVIOUS}$
1	0	0
1	1	1

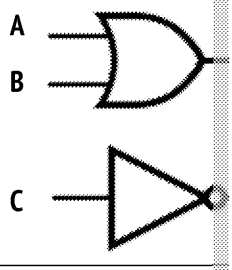
The previous value of Q is stored in Q wh
On the leading edge of the clock pulse, D
either 0 or 1.

6.4 – Progress Check

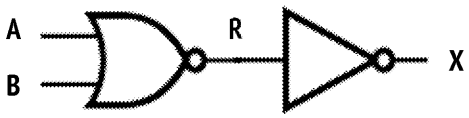
10. Define the terms 'flip flop' and 'D-type flip flop'. (4 marks)
11. Describe the inputs and outputs used by a D-type flip flop. (2 marks)

Logic circuits and Boolean algebra

Logic gates can be combined to form **logic circuits**, for example the NOR and NOT gates shown below with the truth table for the circuit.



Boolean expressions are used in computer programs; when these expressions are evaluated they give a Boolean Logic output of either True or False.



A	
0	
0	
1	
1	

Boolean algebra is used to show logical expressions in the truth table, such as:

R = (A NOR B)

The Boolean expression for the complete logic circuit is:

X = NOT (A NOR B)

Drawing logic diagrams from Boolean expressions

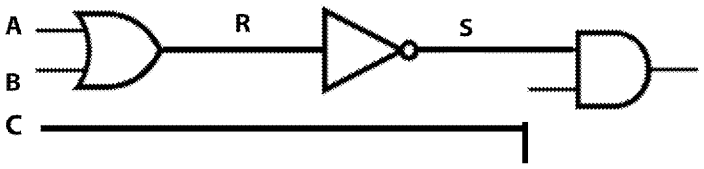
Logic diagrams can be drawn from Boolean expressions, such as: **X = (A OR B) AND (NOT**

Draw complex logic diagrams by first drawing the bracketed terms, so in this case:

1. Draw the logic gate for A OR B
2. Then draw the logic gate for NOT C
3. Finally, draw both outputs connected to an AND gate

6.4 – Progress Check

12. Use the following complex logic diagram to work out the outputs for va



(a) State the outputs R, S and T when the following inputs are:
A = 0 B=1 C = 0 (3 marks)

(b) State the outputs R, S and T when the following inputs are:
A = 0 B=0 C = 1 (3 marks)

(c) State the outputs R, S and T when the following inputs are:
A = 1 B=1 C = 0 (3 marks)

(d) State the outputs R, S and T when the following inputs are:
A = 1 B=1 C = 1 (3 marks)

13. Draw the logic circuit for Q = (A OR B) AND (C OR D) (3 marks)

6.5 BOOLEAN ALGEBRA

Using Boolean algebra

De Morgan's laws and Boolean identities can be used to simplify and manipulate Boolean e
expression can be produced using NAND or NOR gates.

Some useful Boolean identities are shown below, where + is a logical OR and '.' is a logica

AND logic identities	OR logic identities
1 . A = A	0 + A = A
0 . A = 0	1 + A = 1
A . A = A	A + A = A
$A . \overline{A} = 0$	$A + \overline{A} = 1$
A . B = B . A	A + B = B + A
A . (B . C) = (A . B) . C	A + (B + C) = (A + B) +. C
A + (B . C) = (A + B) . (A + C)	A . (B + C) = (A . B) + (A . C)
A . (A + B) = A	A + (A . B) = A

$\boldsymbol{A . B = \overline{\overline{A}}}$

The laws ar

1. Chan
2. Chan
3. Chan
   so:
   $\mathbf{A} =$
4. Chan
   expre
   exp
   (and

Example

Simplify the following Boolean expression:

$$\overline{A.B} . (\overline{A} + B) . (B + \overline{B})$$

$\overline{A.B} . (\overline{A} + B) . (B + \overline{B})$	Original Boolean expression
$= \overline{A.B} . (\overline{A} + B)$	Remove identity $(B + \overline{B}) = 1$
$= (\overline{A} + \overline{B}) . (\overline{A} + B)$	Apply De Morgan's law to $\overline{A.B}$
$= \overline{A} + (\overline{B} . B)$	Factorise for $\overline{A}$
$= \overline{A}$	Remove identity $(B . \overline{B}) = 0$

6.5 – Progress Check

14. Simplify the following (3 marks):

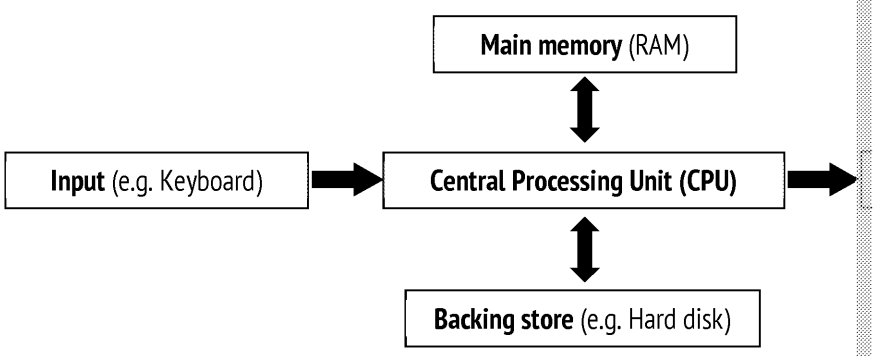
$$\overline{A}.B.C + \overline{A}.C$$

TOPIC 7 – COMPUTER ORGANISATION AND

7.1 INTERNAL HARDWARE COMPONENTS OF A COMPUTE

Internal hardware components of a computer

All ICT systems have these same essential components and some typical examples of device
The main part of the system is the CPU, which is a single chip responsible for all the process



Computer hardware	The physical components of the computer system, which includes The processing hardware is necessary to gain a useable output fro
Backing store	Normally a hard disk, which retains the data written on to it after switched off; it could include other storage devices such as flash m
Input devices	Typically includes a mouse, keyboard and microphone.
Output devices	System output can be printed out by the user or displayed on a co
Power supply	Used to convert alternating current (AC) into low-voltage direct cu internal components within the computer system.

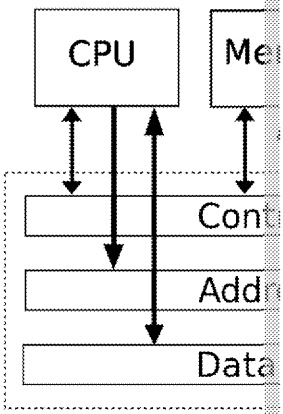
The processor is responsible for following instructions in order to process data and produce a

- Sorting and searching data
- Performing calculations
- Logical decision making
- Control of input, output and storage devices

Bus system

The bus system is composed of the communication links which connect the various parts of a computer.

The three buses involved are the address, data and the control bus; the direction of data flow for each bus is shown.



- **Main memory** stores program instructions and data that are processed by the processor.
- **Address bus** specifies a physical address in main memory and the value that is to be read or written into that address is communicated via the data bus.
- **Control bus** manages data processing; for example, sends a signal to either write from the data bus to a memory address or a signal to read
- **Input and output** – control signals received from the processor include input (read) or o signals are then used to connect a system bus to specific I/O devices; typical I/O device mouse with outputs to monitor and printer.

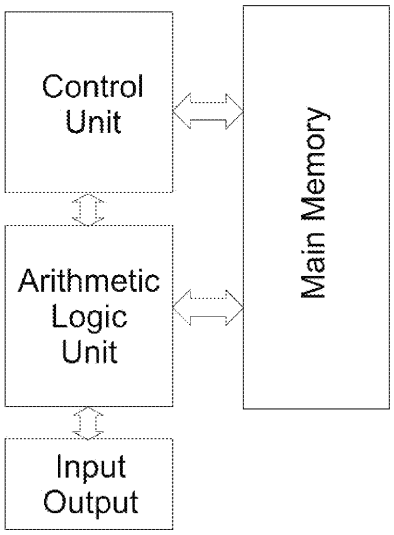
Computer architectures

Van Neumann architecture

The Van Neumann stored program architecture is based on both data and instructions stored in a single memory space.

Data and instructions are transmitted through a shared data bus.

Van Neumann architecture is used extensively in general purpose computing systems.

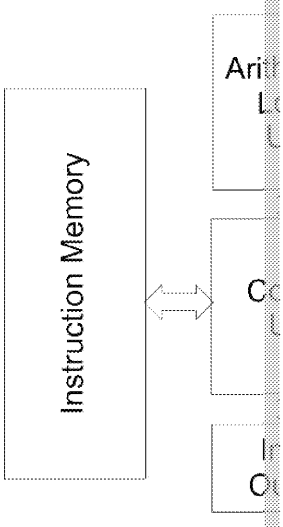


Harvard architecture

The Harvard architecture is based on
being stored in separate memories;
instruction memory serially and data
instruction.

The Harvard technique may be faste
instruction and data can take place

Embedded systems such as digital s
the Harvard architecture extensively
machines and burglar alarms make



Addressable memory

The processor needs to be able to address individual memory locations, so each memory l
numeric code.

To select a memory location the following steps are taken:

1. The processor writes the numeric code into the address bus
2. The processor sends a request to the control bus with instructions to read or wri
3. Finally, the data that is being read from or written to will be transferred via the d

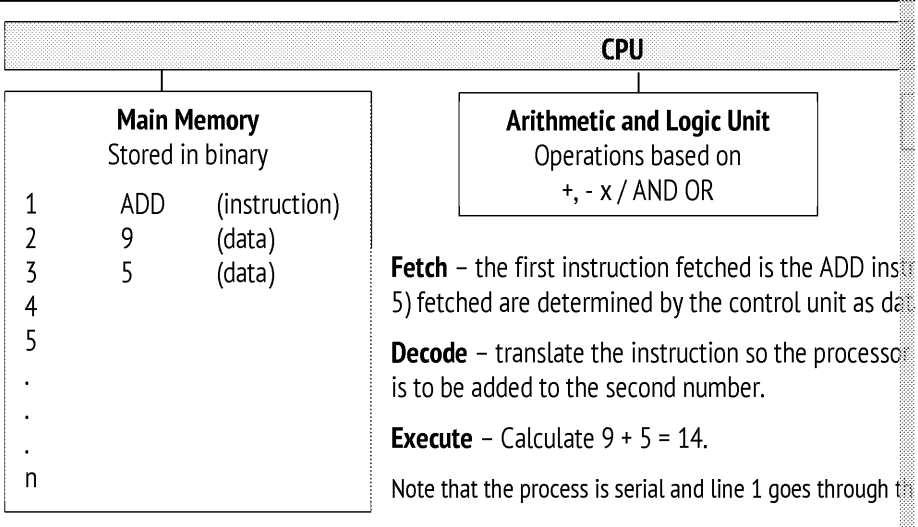
7.1 – Progress Check

1. Briefly describe the function of the following computer architecture term
   (a) CPU (2 marks)
   (b) Main memory (2 marks)
   (c) Address bus (2 marks)
   (d) Control bus (2 marks)
   (e) I/O controller (2 marks)
   (f) Arithmetic logic unit (2 marks)
2. Describe, with the aid of a sketch, the Van Neumann program architecture

7.2 THE STORED PROGRAM CONCEPT

The stored program concept

The program is stored in main memory and machine code instructions are fetched and executed serially in the processor. The example below shows a typical arithmetic operation using the fetch-execute cycle (described fully in section 7.3).



Fetch – the first instruction fetched is the ADD ins
5) fetched are determined by the control unit as da

Decode – translate the instruction so the processo
is to be added to the second number.

Execute – Calculate 9 + 5 = 14.

Note that the process is serial and line 1 goes through t

7.3 STRUCTURE AND ROLE OF THE PROCESSOR AND ITS C

The processor and its components

Arithmetic logic unit	Performs arithmetic and logical operations, such as fixed point and floati point arithmetic, logical operations (AND, OR, XOR) and shift operations. Inputs are from the internal bus and the accumulator, with outputs route to one of the registers.
Control unit	Main function is to fetch program instructions from memory, to decode them and to execute them serially.
Clock	System clock sends a signal to each of the computer components on a regular basis to synchronise all of the computer operations.
Register	A fast memory location that exists in the processor or the I/O controller. The computer consists of general purpose and dedicated registers.

General purpose registers (normally named R0, R1, R2, etc.) can be used to hold instr

Dedicated registers are used by the processor to carry out a specific role:

Accumulator (ACC)	Special register used as fast temporary storage by
Status register (SR)	Used to hold the status of various flags indicating result, carry bit used, overflow error, and interrupt storage are dependent upon the processor involve
Program counter (PC)	Register that holds the address of the next instruct
Memory address register (MAR)	Holds the address of the current instruction being e
Memory buffer register (MBR)	Holds the instruction from the (MAR) and the assoc
Current Instruction register (CIR)	Used to store the instruction that is to be decoded and executed.

7.3 – Progress Check

3. Define the term 'register' and the difference between general purpose an
4. Briefly describe the function of the following dedicated registers:
   (a) Status register (2 marks)
   (b) Program counter (2 marks)
   (c) Memory address register (2 marks)
   (d) Memory buffer register (2 marks)
   (e) Current instruction register (2 marks)

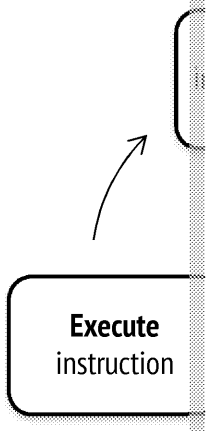
The fetch-execute cycle and the role of registers within it

After the computer is switched on it performs the fetch-execute cycle; this process reads the main memory (RAM) and these instructions are then executed by the processor.

Once the instruction has been executed the process is repeated to read the next instruction. are described below:

Fetch:

1. Program counter (PC) points to next instruction to be fetched.
2. Contents of (PC) copied into memory address register (MAR).
3. The instruction in (MAR) is transferred via the data bus to the memory buffer register (MBR).
4. The contents of the (MBR) are copied to instruction register (CIR) and the program counter (PC) is updated to address next instruction.



Decode:

The instruction in the (CIR) is decoded.

Execute:

1. The decoded instruction is executed.
2. The process is repeated.

7.3 – Progress Check

5. Describe, with the aid of a sketch, the fetch-execute cycle and the role of

The processor instruction set

Machine code instructions are written in binary code that the processor can interpret an

It is convenient to write software in high-level languages; these high-level languages are com code that can be understood and executed by the processor.

The **instruction set** is the set of the machine code instructions that a particular type of p

Two different types of processor can only be compatible if they are able to operate the sam the following operations:

- Arithmetic operations (ADD, SUB)
- Data transfer operation (MOV, OUT)
- Logical operations (AND, OR)
- Jump operations (JMP, JZ – jump if zero)

A machine code instruction consists of an operation or op-code and an operand, as shown in

Op-Code	Operand
4 bit	12 bit

Op-code instructions are the part of a machine code instruction that represents a basic

Operand is value or memory address that forms part of a machine code instruction.

Instructions consist of an op-code and an operand, where the op-code contains a basic mach a value or a memory address.

Some typical examples are shown in the table below:

Op-code	Operand	Machine Operation	Ex
0001	0000 0000 1111	Load into accumulator	Load the contents of the ope
0100	0000 0000 0111	Add 7	Add 7 to contents of accumul
1000	0000 0000 0011	Store to main memory	Store the contents of the acc

* **Note**: you will be expected to interpret op-codes rather than define them in the given con

Addressing modes

Instructions and data are located in memory by using addressing modes; the specification re and direct addressing modes.

Immediate addressing means that the data in the operand is fixed; in other words, it is

This is a very fast addressing mode since the data is readily available, rather than needing to obt

Typical example: `ADD 12` – this instruction could be used to add 12 to the accumulator.

Direct addressing, or absolute addressing, means that the code is directly referred to a

Example: `ADD (1302)` – this instruction adds the contents of memory location (1302) to t

The disadvantage of using code that directly refers to memory addresses is that the code ca typically used on single-program systems, such as a car engine fuel control system.

7.3 – Progress Check

6. Briefly describe the following processor instruction set terms:
   (a) Machine code (2 marks)
   (b) Op-code (2 marks)
   (c) Operand (2 marks)
   (d) Instruction set (2 marks)

7. Compare the immediate and direct addressing modes. (4 marks)

Machine code / assembly language operations based on ARM (Raspberry Pi

Assembly language is used to make machine code instructions more understandable b

ARM is a load-store architecture meaning that memory can only be accessed by:

- Loading from memory into a register
- Storing the result back into memory

Basic machine code operations that can be expressed in mnemonic form (assembly languag

Immediate address examples:

```
LDR r1, #12
ADD r2, r1, #5
SUB r3, r2, #3
STR r3, 1203
```

Immediate address loads the data without reference to an add
 # indicates that the operand is a number

1. Loads the number 12 into the register r1
2. Adds the number 5 to value in r1 and stores result in
3. Subtracts the number 3 from value in r2 and stores r
4. Stores the contents of the register r3 (14) into memo

Direct address examples:

```
LDR r1, 12
ADD r2, r1, 13
SUB r3, r2, 14
STR r3, 150
```

In this case the operand is a memory address

1. Loads data in memory address 12 (4) into r1
2. Adds the data in memory address 13 (5) to r1 and stores result in r2 (making 9)
3. Subtracts the data in memory address 14 (3) from the r2 and stores result in r3 (making 6)
4. Stores the result in r3, which is 4 + 5 – 3 = 6 into memory address 150

Compare is used to compare two values; the result is normally used as a setup for a conditi

`CMP r1, #23`	compares r1 with the number 23 (immediate addressing).
`CMP r1, 23`	compares r1 with the number stored in memory address 23 (di
`CMP r1, r2`	compares r1 with register r2

Branching

Branching is used for conditional statements or unconditional statements

A **label** is a sequence of characters that identities a location in computer source code.

It is commonly used in branch or jump instructions in assembler code.

Unconditional branching is a command where a section of code is jumped over, with n

…	some code
`B Next`	unconditional branch to label 'Next'
…	some more code
`Next`	label 'Next'
…	code continues

Conditional branching is a command where a section of code is jumped over based on

…	some code
`CMP r1, r2`	compares contents of registers r 1 and r2
`BEQ End`	branch to label 'End' if contents of r1 = r2
…	some more code
`End`	label 'End'

Other branches include:

BNE	Branch not equal
BLT	Branch less than
BGT	Branch greater than

High-level to assembly code conversion

Example

```
Total ← 0
FOR X = 1 TO 5
      Total ← Total + 10
END
```

Use r1 to store value of Total and r2 to store the value of X

```
      MOV   r1, #0          initialise Total = 0
      MOV   r2, #1          initialise X = 1
loop  CMP   r1, r2          compare the value of r2 with #5
      BNE   end             r1 = r2 so branch to end of loop label
      ADD   r1, r1, #10     add 10 onto total
      ADD   r2, r2, #1      increment X
      B     loop            branch to start of loop
end   HALT                  loop completed
```

Logical bitwise operator

Logical bitwise operator is where a logical operation is carried out on each column of

In bitwise operations, the '#' symbol in the instructions below indicates that the operand is immediate addressing. Note – where no # symbol is used indicates that the operand is a m

`AND r2, r1, #1101`	Operand1 0011 Operand2 1101 **AND** result **0001**	Performs a bitwise logical A register r1 (#0011) and the The result (#0001) is stored
`ORR r2, r1, #1101`	Operand1 0011 Operand2 1101 **OR** result **1111**	Performs a bitwise logical O register r1 (#0011) and the The result (#1111) is stored
`EOR r2, r1, #1101`	Operand1 0011 Operand2 1101 **XOR** result **1110**	Performs a bitwise logical E the value in register r1 (#00 The result (#1110) is stored
`MVN r2, #0011`	Operand 0011 **NOT** result **1100**	Performs a bitwise logical N The result (#1100) is stored

Logical shift is a bitwise operation where all the bits of an operand are shifted left or r completed the vacant-bit positions are filled with zeros.

These bitwise operations are performed on unsigned integers as the sign bit is not preserve zero. See examples below for further details.

Logical shifts can be useful as efficient ways of performing multiplication or division of uns

- Shifting left by *n* bits has the effect of multiplying it by 2^n.
- Shifting right by *n* bits has the effect of dividing it by 2^n.

Logical Shift Left `LSL r1, r2, 2` operand is shifted left by 2 places	The value stored in places and the resu So before shift After shift

Logical Shift Right	The value stored in
`LSR r1, r2, 5` operand is shifted left by 5 places	places and the resu
Halt simply terminates the program operation `HALT` no operand needed for halt instruction	So before shift After shift

7.3 – Progress Check

8. Convert the following program code into assembly language instruction

```
IF (A > B) THEN
      P ← 3
ELSE IF (A = B) THEN
      P ← 1
ELSE
      P ← 0
END IF
```

Use r1 to store A, r2 to store B and r3 to store P.

Interrupts

Processors have the option to cause an interruption of the normal operation of the system. Interrupts can be provided by hardware (mouse button pressed) or software (program has detected an error or illegal operation).

When an interrupt is generated, the operating system executes an interrupt service routine so, if the interrupt is high priority, it causes the fetch-execute cycle to be immediately interrupted after the completion of the current instruction.

Interrupt service routine process interrupts the fetch-execute cycle as follows:

Store interrupted task	• Current instruction finishes its execution • Program counter contents stored in memory • Register contents stored in memory
Interrupt service routine carried out	• Interrupt number examined and source of interrupt identified • Program counter loaded with start address for interrupt service routine • Interrupt service routine is executed
Continue interrupted task	• Contents of registers from original task restored to memory • Program counter contents from original task restored • Interrupted task continues

Factors affecting processor performance

The factors and their impact on processor performance are outlined below:

Factor	Effect on processor performan
Clock Speed	The clock speed is a key factor in the performance of a computer. It controls the process of executing an instruction as well as fetchin has increased regularly in recent years. Modern computer devices run at a clock speed in excess of 2.5 GHz, second. Computer performance can easily be increased by purchasi the device the more heat it produces and so additional cooling is ne
Number of Cores	System performance can be improved by increasing the number of p using a multi-core processor. A multi-core processor has more than one processor incorporated in dual-core processor will provide two processors on one chip, which processor.
Cache Memory	Cache is high-speed memory that is fitted close to or on the process Programs run faster using cache memory as it can be accessed faste regularly used data and instructions to further improve performance
Word Length	Most modern processors use 32-bit or 64-bit word lengths; the perf an increase in word length, providing that the word length and data So, using a 64-bit word length with a 64-bit bus will allow 64 bits o pulse.
Address Bus Width	The width of the address bus affects the amount of memory that ca allowing more memory to be installed on the system or embedded
Data Bus Width	The width of the data bus directly affects how much data can be ca Where the processor uses a 64-bit data bus, it obviously carries mor processor can work faster. Where word size and data bus width are always be carried out in one single process, which improves perform

7.3 – Progress Check

9. Describe how clock speed, number of cores and word length impact on pro

7.4 EXTERNAL HARDWARE DEVICES

Input and output devices	
Device	**Description**
Barcode reader	A bar code represents a code number for a product and is a set of vertical lines of different thicknesses that represent a number. The lines may give information about: • Country of manufacture • Name of manufacturer • Product code Barcode readers or scanners are used to input data from bar codes: • It scans or 'reads' the barcode by using a visible red light • A light sensor measures the reflected light, where white are black areas so creating an analogue waveform of the bar co • The analogue waveform is converted into digital data that is identify product data • A check digit on the end of the bar code is used to ensure ba
Digital camera	Pictures taken using a digital camera are stored on a memory card a by: • Connecting the camera to the computer via a USB port or • By plugging the camera memory card into the computer car Digital cameras operate as follows: • When a picture is taken the image strikes the camera senso • The sensor records the amount of (RGB) light received and c • The image sensor records in RGB format so that all other co • The picture is then stored as an image file on a memory car file contains a series of digital data for each pixel in the pict • Image files can be stored in RAW uncompressed format that or in compressed format such as JPG or TIFF Image editing software can be used to modify images that have bee from the digital camera into the computer; typical improvements inc • Red eye removal • Cropping or removing unwanted parts of the image • Modifying the brightness/contrast • Changing the image resolution
Laser printer	Laser printers are used in many workplaces and function as follows: • They operate on a page at a time and files that require printing are sent to the laser printer using a page descriptio language • The printer processes this file and creates a bitmap pattern for the page • The printer laser beam scans along and across the drum insi pattern as the page that requires printing; this builds up a p attracts toner (powdered ink) onto the page • The toner is then fused onto paper by heat and pressure, usi The main advantages of laser printers are their print speed; commer of pages per minute and also there is high-quality dry page output.

<table>
<tr>
<td>RFID reader</td>
<td>Radio frequency identification tags (RFID), are fixed to products and be programmed with information, similar to a barcode.

The RFID reader operates as follows:
• RFID tags have an antenna (normally a flat spiral aerial) that communicate with an RFID reader for tracking purposes
• The RFID reader transmits a radio signal which is received by tag and a programmed information code is returned to the re
• This code is then decoded and translated into digital data tha identify the information received.

RFID tags can be used for security purposes in stores to prevent theft set off an alarm when it is removed from the store.

<table><tr><th>Advantages</th><th></th></tr><tr><td>RFID tags do not need a power source as the signal from the ‘reader’ energises the passive tag and causes it to transmit its ID code.</td><td>The RFID ra not have its</td></tr></table></td>
</tr>
</table>

Secondary storage devices

Secondary storage devices are used in computer systems to avoid having to re-enter progra storing a non-volatile or permanent copy. Additionally, data can be stored more than once restoring lost data from the secondary storage device.

<table>
<tr><th>Device</th><th>Description</th></tr>
<tr>
<td>Hard disk</td>
<td>The most common form of secondary storage device is the intern disk drive, where:
• Drive consists of a number of metal disks which have been coated with a special magnetic material
• The disks are mounted on a common spindle and rotate at high speed
• A series of read/write heads move across the disk surface together to access or store the data on the disk
• The hard disk mounted in a sealed unit and is connected to power supply inside the computer

Since the data is stored in this magnetic material the device is kn

Some hard disk drives are not permanently fixed inside the comp the computer; other hard drives are even more portable as they a computer via a USB cable.

<table><tr><th>Advantages</th><th></th></tr><tr><td>Hard disks have a high data transfer rate.

High storage capacity (typically 500 gigabytes to 10 terabytes)</td><td>Where hard can be difficu computer.

Care has to b disks due to</td></tr></table></td>
</tr>
</table>

Optical disk

Optical disks are known as optical storage devices, where:

- The optical disk is a plastic disk with a mirrored surface
- Binary data is burned or pressed onto the surface of the disk as series of 'pits' and 'lands'
- Whichever method is used to create the disk, the 'pit' binary value of zero, whereas the 'lands' have a binary
- Laser beams are used to read the data stored on the d different amounts of light, which can then be decoded

There are different types of optical disk available as follows:

Type of Disk	Storage Capacity
CD	650 Mb
DVD	4.7 Gb
Blu-ray	25 Gb

Blu-ray disks can be increasing their capa

DVD disks can also b format, increasing th

Advantages	
Portable device that is cheap to produce – typical blank disks cost between 10p–50p each.	Care need the shiny
Reasonable storage capacity for home and faster access time than magnetic tape.	Less stora is unsuita
Optical drives are compatible with CD and DVD disks so data can be read from either media.	Access tim SSD devic

Solid-state disk (SSD)

Solid-state disks act in a similar way to a hard drive except they are flash memory secondary storage devices where:

- They are based on non-volatile NAND flash memory w a controller to manage pages, blocks of data and the complexities of writing
- The flash memory cells are grouped into a grid that is separated into sections called 'pages', into which the d
- A block consists of many pages and pages cannot be o has to be erased before the page can be overwritten

	SSD compared to hard d
Speed	SSDs perform faster than hard drives as there are n consequently they can read, write and access data f Latency is a feature of hard disks as they are slow t and position read/write heads over the disk to acce
Cost	SSDs are significantly more expensive to purchase t tend to be smaller capacity than hard disk drives.

7.4 – Progress Check

10. Describe the operation and uses of an RFID reader. (6 marks)
11. Compare the relative advantages of using hard disks or solid-state dis storage. (4 marks)

TOPIC 8 – CONSEQUENCES OF USES OF C

8.1 INDIVIDUAL, SOCIAL, LEGAL AND CULTURAL ISSUES A

Individual and social issues

Morals are a set of principles that apply to an individual, but moral standards might be dif for individuals based on what they consider to be 'right' or 'wrong'.

There are many definitions of ethical standards; for example, 'it is a set of principles to pr what is good for individuals and society'. In computing, ethical standards are the behaviou expected by the organisations to which the individual belongs.

Ideally individual moral codes would be similar to the ethics practised by computer profes However, individuals are not well regulated and there is a tendency to act outside of the l legislation has been introduced to try to prevent this behaviour.

The information below is a shortened version of the widely used **Software Engineering Co Practice**, created by ACM (Association for Computer Machinery) and the IEEE (Institute of E

> ***Software Engineering Code of Ethics and Professional Prac***
>
> ***PREAMBLE***
> *Software engineers shall commit themselves to making the analysis, spec testing and maintenance of software a beneficial and respected professio commitment to the health, safety and welfare of the public, software eng following Eight Principles:*
>
> 1. *PUBLIC – Software engineers shall act consistently with the public in*
> 2. *CLIENT AND EMPLOYER – Software engineers shall act in a manner their client and employer consistent with the public interest.*
> 3. *PRODUCT – Software engineers shall ensure that their products and highest professional standards possible.*
> 4. *JUDGMENT – Software engineers shall maintain integrity and indepe judgment.*
> 5. *MANAGEMENT – Software engineering managers and leaders shall s ethical approach to the management of software development and m*
> 6. *PROFESSION – Software engineers shall advance the integrity and r consistent with the public interest.*
> 7. *COLLEAGUES – Software engineers shall be fair to and supportive of*
> 8. *SELF – Software engineers shall participate in lifelong learning regar profession and shall promote an ethical approach to the practice of t*

See **www.acm.org/**

There are many ethnical responsibilities for software engineers and computer scientists to their disposal is not misused; typical ethical issues to be aware of are:

- To develop software that respects the privacy of those users that will be affected
- To only use accurate data derived by ethical and lawful means.
- To maintain the integrity of data.
- To not knowingly use software that has been obtained illegally.

Legal issues

The following legislation is important when creating computer systems:

- Data Protection Act
- Copyright Law
- Computer Misuse Act

Data Protection Act (1998)

The Data Protection Act was introduced to ensure that the data held on clients conformed t
held securely, being up to date and not kept longer than necessary.

Keeping data secure is a key feature of this legislation and so when developing computer s
add a range of software methods to help protect client data, such as:

- **Passwords** entered in to software applications should only be accepted if they ar
break; strong passwords are created by using mixtures of numbers, letters, and s
case so that the final password does not look like a word.
- **Encryption** is used to make stored data more secure, by making it unreadable to p
decode it. This method is commonly used to protect data transmitted over the Int
- **Selective drop-down menus** are sometimes used as a security method to add lett
typing them; this prevents key-logging software from viewing the systems and ga

Personal data moral issues include:

- Misuse of personal data – selling it to businesses that use the data for a different purpose to the original reason it was collected.
- Data security – personal data is stored on networks that can be broken into and stolen by hackers. In some cases government employees have lost laptop computers with unencrypted personal details of taxpayers which have got into the wrong hands, causing privacy issues.

Copyright Design and Patents Act (1988)

The Copyright Design and Patents Act introduced to protect the intellectual property of inc
and produce materials based on their own individual ideas.

The computing industry has grown tremendously in recent years with a great many new co

Copyright legislation is useful in protecting the following aspects of computer technology:

- **Piracy** is the illegal copying of software for either personal use or business use; t
can include illegal downloading of games and music as well as commercial softw
- **Theft** of hardware and software ideas and innovations. In an industry that moves s
time to patent your invention before you release it on to the open market. Many c
their rivals' products with the express purpose of copying their ideas, which saves
expense on research and development.

Protecting your copyright is especially worthwhile when you or your organisation have invented a new hardware or software concept.

There are many websites that can help the creator to protect and patent their work. The m
is that they make the public aware of their intellectual property rights; this can be achieve
documentation with their products, stating that their designs are copyrighted, can't be mo
'reverse engineering' techniques can be used to produce replicas.

Copyright issues include:

- Unauthorised use of software – downloading or copying software illegally without purchasing the necessary software licence
- Illegal copying of music and films
- Illegal copying of web content

Computer Misuse Act (1990)

The Computer Misuse Act was introduced with the express purpose of preventing attacks on ICT systems to commit crimes or to damage the system; this legislation made hacking and the introduction of a computer virus into criminal offences.

Hacking is the practice of breaking into computer systems and it is essential that preventative measures are taken. The main techniques are to utilise a **firewall** and to set up some intrusion detection.

ICT systems are constantly communicating with the outside world, which involves connect associated difficulty of effectively policing access to the system. A firewall is a combinatio designed to check the integrity of incoming messages and requests for service from the sy

A computer **virus** is a program designed to cause damage to a computer system. The use o helps to minimise the risk from viruses; this software searches the computer system for vi

Spyware can be loaded into a computer system as a software virus, so it is important to ru prevent and detect spyware from being installed and to remove any spyware that has prev

Computer misuse issues include:

- Unauthorised access by hackers for fraud purposes or to gain access just for the c

Regulation of Investigatory Powers Act (2000)

Regulation of Investigatory Powers Act was introduced to explain the powers that public authorities, such as the intelligence services, the police and Customs and Excise have available when investigating crime or terrorism.

The mains parts of this legislation are that the authorities can obtain information from:

- ISPs providing access to customer communications
- Telephone tapping
- Monitoring individuals' Internet activities
- Accessing protected information, if encrypted the authorities have the right to de that means the encryption key must be handed over.

Cultural and communication issues

In recent years there have been many developments in computer science and digital technology which have had a major impact on information flow and communication throughout the world.

This has led to the ability to analyse, monitor and distribute personal information on a large scale. Although in some cases the consequences of this improved communication can be beneficial to society, there is a risk that it can also be harmful.

Students are expected to have an understanding of the consequences and uses of comput

- One method to gain this knowledge is by making use of current technology news
- Reading case studies will develop an understanding of the issues involved
- If the article does not give a balanced view of the issues, it might be useful to co viewpoint

8 – Progress Check

1. Compare the terms 'morals' and 'ethics'. (4 marks)
2. Briefly discuss some of the ethical responsibilities faced by software engi

9.1 COMMUNICATION

Communication methods

Data transmission refers to the transfer of data between two or more digital devices.

Serial data transmission is where data is transmitted one bit at a time along a single c

Parallel data transmission is where data is transmitted more than one bit at a time al

Serial vs Parallel	
Speed	If a parallel data bus had eight cables it would, in theory, transmit data e cable used in a serial bus.
Interference	There is interference between the parallel wires which reduces the band parallel transmission bit rate is limited by interference.
Connections	Connecting cables are short to minimise the interference effect with para serial connection there is no interference or noise problem so connecting
Cables	Parallel data transmission uses more cables than serial data transmissio expensive to produce and more complex than serial cables.

Synchronous data transmission is where a block of data is transmitted along with a co signal; this will ensure that the data transmitter and receiver are synchronised.

Most network protocols make use of synchronous transmission, where data is sent in pack

Asynchronous data transmission is where a data stream is not synchronised and transmitted at fixed time intervals.

It is only synchronised for the transmission period by making use of start and stop bits; this method is normally used for communications over telephone lines.

Data transmitted asynchronously includes a start bit inserted for each unit of data and a stop bit to indicate the termination of the data transmission.

St un tra

St un tra

Communication basics

Baud rate is the number of symbols (or symbol changes) that are transferred across a

Baud rate is based on the number of bits encoded in each signal change; so, for example, signal change the bit rate will be eight times higher than the baud rate.

Bit rate is the number of bits transferred across network in a set amount of time; norm (bps).

Bandwidth is the speed of a network or the maximum rate at which data is transferre and indicates the maximum amount of data that can pass from one point to another i proportional to bandwidth.

Latency is the term used in a packet switched network to measure the time delay bet and the destination receiving that packet.

Ping is a network utility used to measure latency; it works by calculating the time taken fo between its source and destination.

A **protocol is** a set of rules or standards which computers use for communication.

An example of a protocol is **TCP/IP** which provides a unique identifier for a device or com transmission control protocol (**TCP**) sets the standard for the delivery of information packe

9.1 – Progress Check

1. Compare and contrast 'synchronous' and 'asynchronous' data transmissio
2. Describe the following communication terms:
   (a) Bit rate (2 marks)
   (b) Bandwidth (2 marks)
   (c) Latency (2 marks)
   (d) Protocol (2 marks)

9.2 NETWORKING

Network topology

A network **topology** is a way of describing the interconnections and cabling of a group

Physical topology is how the devices or a group of computers are physically connected

Logical topology is how the network devices communicate with each other.

Logical classification of network topologies has the same characteristics as their physical c
paths for a logical bus network follow the same route as those in a physical bus network.

Physical Star Topology

The physical **star topology** is based on connecting each workstation to a single point such as a hub which may also be linked to a file server.

If one network cable breaks, the workstation connected to it also fails, but it does not affect the rest of the network.

However, if the central hub fails the whole network will be inoperative as each workstation relies on the central hub for communication.

Advantages	D
If one of the network cables breaks only the computer connected to that cable is affected. Fast response time and no problems with data collision as each workstation has its own cable. Security can be installed at the central hub.	All communication take fails the whole network Uses the most cable wh install. Also long cable degrade.

Physical Bus Topology

When a physical **bus topology** is used, each workstation is connected to a single cable (often referred to as the 'backbone') which links all of the workstations.

The file server is connected to the main bus for data distribution to all the workstations.

Data can be transmitted in either direction along the main cable, and workstations can communicate with their peers.

A range of peripherals can also be connected to the main bus for shared usage.

The physically wired star topology can be dynamically reconfigured into a logical bus topo protocols and specialist equipment such as routers and switches.

Advantages	D
If one workstation fails it does not affect the rest of the network. Is cheaper to install as it uses the least cable as the cost of network cabling (particularly fibre optic) and the cost of network cable installation can be significant.	If the main network cab workstations can access If there is heavy networ fall off dramatically. If the main bus fails all

9.2 – Progress Check

3. (a) Define the term 'network topology'. (2 marks)
   (b) Explain the difference between physical and logical topology. (2 mark
4. (a) Explain, with a sketch, the physical star topology. (2 marks)
   (b) Describe one advantage of the physical star topology. (2 marks)
   (c) Describe one disadvantage of the physical star topology. (2 marks)

Client–server and peer-to-peer networking

Client–server networking

ⓘ A **client–server** model is where the workstations in any network design use the server to provide a service.

ⓘ **Client** is a computer or workstation on a typical network.

ⓘ **File server** is the computer with the main processing power and storage that interacts with the clients.

The client–server model has become one of the central ideas of network computing. Clients are the many workstations on the network and the file server is the more powerful system that interacts with the clients.

The client–server system diagram shows a range of client devices connected via the Inter

In a school context: a student logs on to a workstation and opens a word processor applic document for editing (requested from the server) and the document is sent to them from t changes. Whenever the document is saved the changes will be made to the file server loca

Advantages	Disac
The system facilitates a centralised backup.	Server failure can cause the whole
Centralised data which is more consistent as there is only one copy in use. Any lost data can be restored centrally for all users.	Network management is a skilled a maintenance.
Security policies for access control and associated usernames are managed centrally.	It is expensive and time-consumin network operating system, which i clients and the labour involved in t

Peer-to-peer networking

Peer-to-peer networks are different from client–server networks as they do not have special workstations which are used as servers. Instead any workstation on the network can load information from the hard disk or use a local printer for any other workstation, as all workstations have equal status.

In the diagram it should be noted that all workstations are linked to each other; complexity of cabling can be reduced nowadays by use of Wi-Fi.

Peer-to-peer networks are commonly used as local area networks (LANs) for general administration by either small businesses or in the home.

Note that in peer-to-peer networks all workstations need to be linked but it does not need to be a direct link.

9.2 – Progress Check

5. Explain, with a sketch, peer-to-peer networking. (2 marks)
6. (a) Describe the client–server network model. (2 marks)
   (b) Describe one advantage of the client–server network model. (1 mark
   (c) Describe one disadvantage of the client–server network model. (1 m

Wireless networking

Wi-Fi allows devices, such as smartphones, tablets and laptops to communicate wirel

A **wireless access point** is device that allows wireless devices to connect to a wired n

A **wireless adaptor** performs a similar function to a **network interface card (NIC)** but wirelessly. The wireless adaptor can be built into the computer or it can be a portable dev fitted into a USB port.

In a home or office network a wireless router transmits a Wi-Fi signal that can be shared b more than one device. This approach is used to share an Internet connection between sev devices using a mixture of Wi-Fi and Ethernet cable connectivity.

WPA/WPA2 (Wi-Fi Protected Access) are encryption protocols designed to protect a W

This protocol is used whenever an attempt is made to connect to a secured wireless netw security key or passcode. This ensures that the connection is secured with encryption.

In some cases the wireless access point has option to choose the security protocol; where it is the latest and most secure encryption version.

SSID (service set identification) is a unique 32-character identifier that is used to nam

It is necessary to ensure that a device is connected to the correct WLAN (wireless local area network); the normal approach to checking for this connectivity is to put a copy of the SSID into the header of each packet of data being sent.

This SSID code is unique to a specific WLAN and only devices that are programmed with t WLAN.

A MAC (Media Access Control) address is the physical address of a networking device identifier assigned by the manufacturer and is stored in the device's read-only memor

Security can be improved on a wireless network as follows: the router for a wireless netw to a white list of computers – these computers are identified by their unique MAC address addresses of all the devices that are approved, accepted or recognised by the system.

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

Carrier Sense Multiple Access with Collision Avoidance (**CSMA/CA**) operates by the c that it is about to transmit data. Other computers can then avoid a collision by delayi

CSMA/CA access methods can be used both with and without the Request to Send / Clear

With RTS/CTS	Wit
1. RTS signal is sent by the sender of the package 2. then a CTS signal is sent by the intended receiver of the package 3. consequently the sender and receiver are aware of a data transmission and hold off for the duration of the main transmission	1. The computer want if the channel is 'idl 2. then it is able to se 3. if the channel is se and try again

The CSMA/CA method is widely used in WLANs although it has the disadvantage of reduci increases the amount of network traffic.

9.2 – Progress Check

7. Describe the following networking terms:
   (a) Wireless adaptor (2 marks)
   (b) Wi-Fi protected access (2 marks)
   (c) Service set identification (S
   (d) MAC address (2 marks)

9.3 THE INTERNET

The Internet and how it works

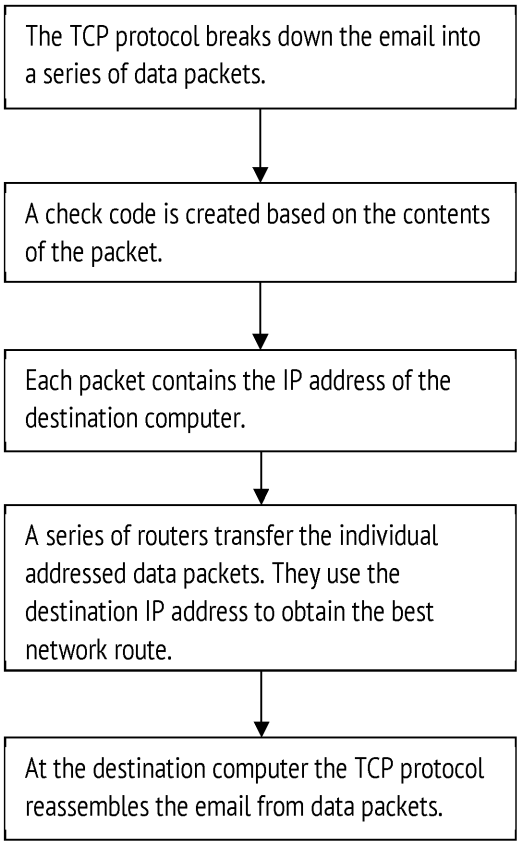
The **Internet** can be thought of as a massive network of networks, whereby it connects mi
forming a network in which any computer can communicate with any other computer prov
the Internet. Information that travels over the Internet does so using the TCP/IP protocol (
Internet Protocol) to transport data packets over the Internet.

Packet switching

In networks, data is both transmitted and received. For example, if you download a web page, an email or a file, the data is broken down into a series of packets; these networks are known as packet-switched networks.

Packets can be defined as 'data that is sent over a network in manageable amounts; the actual size and structure of a packet is determined by the protocol (or rules) being used'.

The **TCP/IP protocol** is used to transfer an email using the simplified flowchart diagram below:



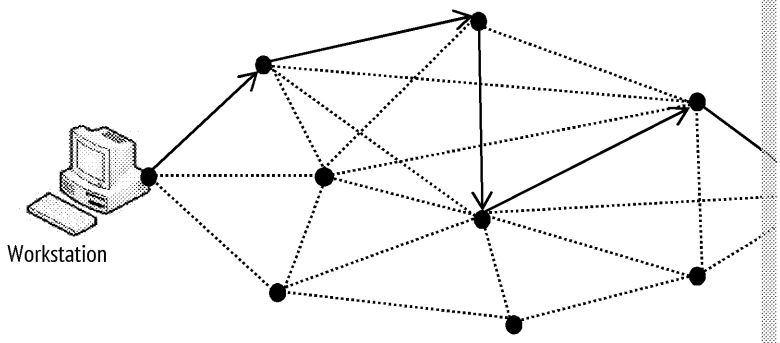
Routers and gateways

Gateways are used where the networks to be connected are of different types; then the job of passing data between them is more complicated. Data that is sent from one network to the other will, therefore, need to be converted from the format that is used on the sending network into the format that is used on the receiving network. This process is carried out by a gateway.

Router – devices called routers are used to determine an efficient route for data transfer between computer systems and to transmit web pages to users throughout the world.

Routing

Internet data is transmitted over between web servers and workstations using packet-swit



The router transmits package data between the sender and the receiver via a series of noc diagram above there are many alternative routes that could be taken to transmit data to th shown with a solid line and the alternative routes are shown with dotted lines.

Routers find the ideal route to take, using sophisticated routing algorithms; each router fo to the next router; the routing table contains all the necessary information on the alternat sender and receiver.

Uniform resource locator (URL)

Uniform resource locator refers to the location of a web resource on the Internet or a com particular website, file or document on the Internet and is displayed in the address bar of

The example below is a URL for a Computer Science course companion file on the ZigZag

http://www.zigzageducation.co.uk/synopses/6060-aqa-computer-science-course-comp

In the example above:

http or hypertext transfer protocol is used to indicate the file is a website	**www** indicates the resource will be located using a World Wide Web server	**zigzageducation** is the name of the organisation that is providing the resource	**co.uk** is the type of organisation used and their country code	**sy** fo re

9.3 – Progress Check

8. Describe data transmission using the packet-switching method. (6 marks)
9. Explain the function of the following terms:
   (a) Gateway (3 marks)
   (b) Router (2 marks)

IP address

Every device on a network needs a unique identifier to ensure that data is sent to the spec computer that requests it. The unique identifier for a computer in a network is known as t address and consists of the network ID and the host ID.

The IP address is needed to allow one computer on a network to communicate with the se or any other device. It is also widely used on the Internet, which operates in a similar way smaller network.

Domain name

The most commonly used method for accessing a website is to enter its web address or dor name which is more commonly known as a uniform resource locator or URL.

An example of a domain name is **google.co.uk**, where:

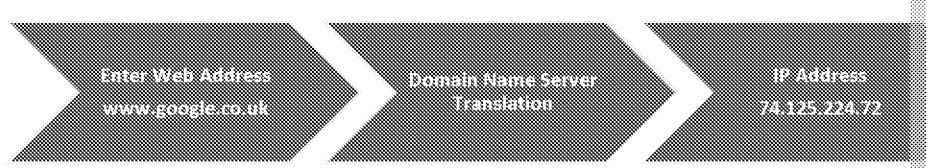
- google is the name of organisation
- .co indicates the type of organisation
- .uk indicates that the organisation is registered in the UK

Domain name server system

The most commonly used method for accessing a website is to enter its web address or dor known as a uniform resource locator or URL.

IP addresses consist of four numbers of up to three digits, separated by dots. Domain nam addresses; for example, it is easier to learn or type in **www.google.co.uk** than the IP addre

When we type in a domain name into a web browser, it has to be converted into an IP add website. This conversion takes place by using the domain name system (DNS), which keeps used and translates them into IP addresses when needed.



Another service provided by the domain name system is registering new domain names ar involved in collecting any fees for domain name registration.

The main advantage of using domain names is that they are easy to remember in preferen the conversion is carried out automatically by a domain name server. Also, companies can that reflect their type of business.

9.3 – Progress Check

10. Define the following terms:
    (a) IP address (1 mark)
    (b) Uniform resource locator (1 mark)
    (c) Domain name server (1 mark)

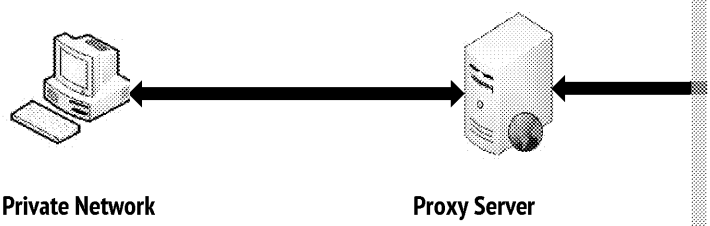
11. Explain how an IP address is accessed using the DNS system. (4 marks)

Internet Security

A **firewall** is used to prevent unauthorised requests from hackers to gain access to the network or computer systems via the Internet.

ICT systems are constantly communicating with the outside world, which involves connection to public networks and the associated difficulty of effectively policing access to the system.

Firewall security can be achieved using the following techniques:

Technique	Detail
Packet filtering	Packet filtering is where the firewall analyses data packets that are atter blocked unless it conforms to a set of rules; typically, the filters are set u packets to view the source of the data. The rules can be set up to block c from a recognised source.
Stateful inspection	Stateful inspection, often termed dynamic packet filtering, is a more secu packet filtering. Each data packet is examined, and the state of active co numbers used is recorded. Data packets may be rejected if they come fro
Proxy server	A proxy server processes the information received from the Internet and network. Therefore, the website host is not in direct contact with the priv transmitted via the proxy server, as shown in the diagram below. 

Encryption

Encryption is widely used to make sure that data transmitted on a network is protected from hackers. It is the process of coding files before transmission, and encryption ensures that the information is only readable by the person or persons who have the encryption key to decode it.

Symmetric encryption

Data **sent** after encryption using a key	Encrypted data **received** is decrypted using a key
Encryption key **sent** to receiver separately	Same key used by **receiver** to decrypt data

Asymmetric encryption

Data **sent** after encryption using a **public** key	Encrypted data **received** can only be decrypted using a **private** key (only known to the receiver)

The main advantage of asymmetric encryption is that the key to decrypt data is not transm
Also, it is exceptionally difficult to obtain details of the private key by inspection of the re

Digital signatures and certification

A **digital certificate** is issued by a certification authority and contains information that can be used to identify the user, the organisation, their email address, their country and the user's public key. When using asymmetric encryption, the recipient can view the digital certificate attached, establish that the message is from a trusted source and use their associated private key to decrypt the message.

A **digital signature** is a different method used to determine the authenticity of the message source by checking an encrypted and certified digital signature. Digital signatures use a mathematical technique based on the hashing algorithm, where the encryption key is based on a particular hash value.

Security threats

Malware or malicious software is a computer program that is installed on a computer system without the owner's consent; the main aim of malware is to damage the computer system or to perform uninvited actions that compromise system security.

The security threats that are dealt with on this course are:

- **Viruses** – computer viruses can be spread by email attachments and can cause damage, such as deletion of data or corruption of data. In extreme cases the contents of the hard disk can be deleted.
- **Worms** – the self-replication of these stand-alone programs can use up system resources, which causes the slowing down or halting of other tasks by using system bandwidth; worms spread around networks and cause disruption by increasing traffic rather than by altering files.
- **Trojans** – a Trojan can be inadvertently installed as it is hidden within another file, so the user is unaware of it. Trojans can be extremely dangerous, causing problems by deleting files, reformatting disks or crashing computers.
  In some cases, Trojans install spyware by providing a back door into the system to spy on user activities, such as monitoring user keystrokes or user activity.

Security protection methods

The following approaches can be taken by the system administrator to reduce the security ris
viruses:

- The use of an up-to-date virus scanner or **anti-virus software** helps to minimise the searches the computer system for viruses and deletes them once detected.
- Spyware can be loaded into a computer system as a software virus, so it is importan which will prevent and detect spyware from being installed and remove any spywar
- **Intrusion detection systems** (IDS) are designed to monitor the network or computer an incident is detected, a report is produced which is sent to the network managem risk to the system.
- **Encryption** of data files using the techniques described above prevents hackers fro if they can intercept it.
- Set up and configure a **firewall** using packet filtering, proxy server and stateful pack incoming messages and requests for service from the system.
- Check the **digital signatures / digital certification** of downloaded data to ensure th and that it is up to date.
- Ensure that operating system and network programs are updated on a regular basis.

- Ensure that all data is backed up on a regular basis so that the system can be recove damage data and files on the system.

Programmers and users can take the following steps to alleviate the impact of security thr

- Only use commercial software that was purchased from a well-known and reputable
- Test and develop new software on a stand-alone computer, being careful to check f uploading the software to other networked computers.
- Only open attachments or click on pop-ups from known and trusted senders.
- Use password protection on files and programs.
- Encrypt all data files.
- Choose a programming language that is designed to avoid basic vulnerabilities to s

Set up security permissions and access rights to prevent the modification of source code b carry out these changes.

9.3 – Progress Check

12. Define the following terms:
    (a) Firewall (2 marks)
    (b) Packet filtering (2 marks)
    (c) Stateful inspection (2 marks)
    (d) Proxy server (2 marks)
    (e) Symmetric encryption (2 marks)

13. Explain the differences between viruses, worms and Trojans. (3 marks)

9.4 TRANSMISSION CONTROL PROTOCOL / INTERNET PRO

TCP/IP

The following four layers are part of the TCP / IP stack:

Layer	Description
Application	The data that is being sent is encoded into a format that is understanc
Transport	The data is split into parts suitable to be fitted into a data packet. Eacl to indicate the port it will be delivered to and is also assigned a numb data packets can be correctly reordered once they have been received.
Network	The network layer attaches the IP address of the sender of the data an receive the data.
Link	The MAC address for the hardware device sending the data is added, a device receiving the data.

Process and connection identification

The TCP / IP process contains an identifier termed as a **socket**, that is based on its IP addr assigned to. Typical socket notation is <IP Address>:<Port Number>

MAC address

The **MAC** (media access control) address is the physical address of a device such as a **NIC** (identifier assigned by the manufacturer and is stored on the network interface card in a RO MAC addresses uniquely identify a network adaptor on a LAN (local area network); on a LA access the network traffic.

Security can be improved on a wireless network as follows: the router for a wireless netwo to a list of computers – these computers are identified by their unique MAC addresses.

Ports

TCP/IP networks have ports, which are logical connections that are used by a client progra networked computer.

Well-known ports – these are ports that have numbers that are specifically pre-assigned a need to use the well-known ports that are the destination ports for a client request and, th service. So, for example, a server processes email based on the use of the following ports: 110 which is a POP3 port.

Client ports – when a server responds to a client request the port number the client is usi port of the request is used by the server to send their reply. Clients assign a temporary por known port.

9.4 – Progress Check

14. Explain the role of each of the following layers in the TCP/IP stack:
    (a) Application layer (2 marks)
    (b) Transport layer (3 marks)
    (c) Network layer (2 marks)
    (d) Link layer (2 marks)

Standard application layer protocols

Protocol is a set of rules or standards; the standard application layer protocols are:

Protocol	Function
FTP	File transfer protocol (FTP) – a TCP network protocol used for file tran
HTTP	Hypertext transfer protocol (HTTP) – a protocol to outline how files su are transmitted on the World Wide Web.
HTTPS	Hypertext transfer protocol secure (HTTPS) – similar functionality to t transmitted is encrypted.
POP3	Post office protocol v3 (POP3) – protocol used to receive email data v messages into text for display in a user email application.
SMTP	Simple mail transfer protocol (SMTP) – protocol used to send email da provided where a connection cannot be achieved between the sender a
SSH	Secure shell (SSH) – protocol used to gain access to remote computer administrators to control web servers remotely.

File transfer protocol (FTP)

File transfer protocol (FTP) is the set of rules that are generally used to download or uploa the Internet.

Typical use of FTP is where a website developer uploads newly created web pages of their website.

FTP is based on the client–server approach where users need to sign in to the server to pr example is online shopping sites, so the user needs to sign in with a username and passwo exchanging information with the server. In some cases, the FTP server can be configured s doesn't need to log in to access the server's files.

Secure shell (SSH) protocol

Secure shell is a computer application that allows the user to log on to another networked SSH provides secure connections and robust authentication where commands can be exec can be transferred between the machines.

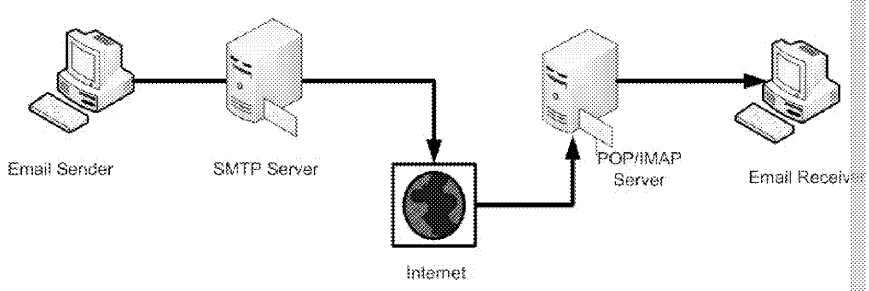
This technique is based on the client–server approach, where the user is the client and the server or host.

SSH can be used to transfer files in a similar way to FTP, but with SSH the data that is tran encryption. Typically, it is used as follows:

- Secure command shell can be used by the system administrator to log in to the server as to change document permissions or to manage user accounts without compromisin
- Secure file transfer can be used, for example, to set up an extranet for sharing files w
- To transmit or modify data at the server.

Secure command shell typically makes use of a simple command line interface; this requir commands and the syntax which accompanies them.

Email protocols and mail server



The schematic diagram above shows the main compounds used in the transmission and re

The email server is a specialist network computer that performs the following functions:

- Sends emails using the simple mail transfer protocol (SMTP); the data is transmitted f
- Contains a set of rules for emails that are handled; for example, file attachments migh
- Receives emails using post office protocol (POP3); incoming data is received via port
- Contains a database of network user accounts so that emails can be routed to the cor
- Contains storage space to store all emails incoming and sent email messages

Web server

Web server is a network computer whose function is deliver web content to clients ov

The web server is a physical server that uses a server operating system and contains the a establish communication using HTTP (hypertext transfer protocol). It can host one or more traffic from clients to the website.

The website data that is stored on the web server consists of the web pages for that site. W standards to ensure that web pages are displayed correctly on all browsers and hardware.

HTML is a mark-up language and has become a standard for web page creation because it web page, and it can be written in a wide variety of software applications from Notepad to

9.4 – Progress Check

15. Describe the function of the following application protocols:
    (a) FTP (1 mark)
    (b) HTTP (1 mark)
    (c) HTTPS (1 mark)
    (d) POP3 (2 marks)
    (e) SMTP (2 marks)
    (f) SSH (1 mark)

Web browser

Web browser is a software application that is used to navigate and view Internet sour

Web browsers are a user-friendly method of finding and displaying websites and informati

We can select a website to display using the following alternative methods:

- By typing a domain name (URL) into a web browser
- By choosing a website from the result of a search
- By selecting the domain name from a list of bookmarks

Next, the domain name has to be converted into an IP address so that it can connect to th

This conversion takes place by using the domain name system (DNS) which keeps details o translates them into IP addresses when needed.

Once the IP address for the website is obtained, we can connect to the web server host to

9.4 – Progress Check

16. Define the term 'web browser' and list three alternative methods used to (4 marks)

IP address structure

The TCP/IP protocol is used as a standard on most networks today; this protocol provides computer, known as its IP address.

The addressing technique used operates in the same way as a normal postal address, whe address based on the unique house number and post code.

IP addresses consist of four numbers of up to three digits, separated by dots. For example, unique IP addresses, including: **74.125.224.72**

The first two numbers represent the **network address**; in this case: **74.125**

The last two numbers represent the **host address** of the device on the network; in this cas

The IP address contains a **network identifier** that identifies the network on which a device or computer can be found. The network ID is needed to authenticate access and connection to the server and applications of the network identified.

A **host identifier** can also be found in the IP address, which identifies a specific device on the network. The host ID (or host address) is used to identify any device on the network, such as a workstation or printer that has a network connection and network interface card

Subnet masking

Subnetting is used to divide the IP address into a network address and the host addresses. The subnet mask is a number that is used to mask the IP address; it consists of a series of 0s and 1s, and the host address is identified by executing a logical BITWISE AND operation.

Subnetting permits the network administrator to further divide the host address into two or mo security reasons.

The example below is shown in binary, using a subnet mask of 255.255.240.000, which ens word remain unchanged using a BITWISE AND operation.

Subnet mask	255.255.240.000	11111111 . 11111111 . 11
IP address	171.151.033.036	10101011 . 10010111 . 00
Subnet address	171.151.032.000	10101011 . 10010111 . 00

IP standards

There are currently two IP address standards known as v4 and v6.

IP standards have needed to change to accommodate the growth of the number of Internet d each device to have a unique IP address.

IP address v4 is based on the original 32-bit code.	**IP address v6** is based on a 128-bit c
It is written as a set of four decimal numbers of up to three digits, separated by dots.	It is written as a set of eight groups o separated by colons.
For example: **74.125.224.72** is the address for Google.	For example: **1A23:0000:0001:011**

Eventually all IP addresses will be in v6 format, but both systems are in use at the time of wr

Public and private IP addresses

A **public IP address** is where a device is assigned to permit direct access routed via the Internet; these IP addresses are totally unique and routable.	A **private IP address** private network; for
Private networks can be connected to the Internet via a router or a proxy server, in which case the Internet connects to the public IP address of the router / proxy server.	This private IP address network. Non-routable a within the private netw

Dynamic Host Configuration Protocol (DHCP)

Dynamic host configuration protocol (DHCP) is a network protocol in which IP addresse devices when they connect to the network. In the case of dynamic addressing, a device m each time that it is connected to the network.

The DCHP server contains a list of available IP addresses that are automatically assigned to d

Where **static IP addresses** are used, the network administrator has to manually configure the s for a device; this can be time-consuming and can result in errors where two devices are config

The advantage of using **dynamic IP addresses** is that no administration is necessary and the of the IP addresses connected to the network.

9.4 – Progress Check

17. Define the following terms: (a) Network ID, (b) Host ID and (c) Subnet mask

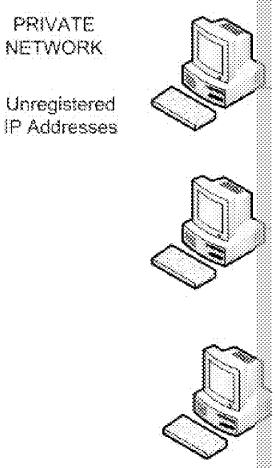
Network Address Translation (NAT)

Network address translation is the technique used to assign a private network a registered public IP address which can then be mapped to the private IP addresses of the devices in the network.

The translation table can be used to look up the links between each internal private IP address and the public IP address for the router.

The benefits of this technique are:

- The private IP address is hidden from the Internet, ensuring it is more secure from unauthorised access.
- The number of public IP addresses that need to be registered by an organisation is limited, saving costs and administration.



Port forwarding

Port forwarding is a technique used to route data to private IP addresses using additi

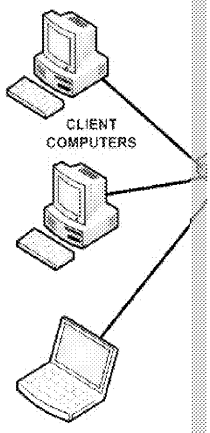
The network address translator (NAT) forwards a communication request from a public IP a address using a translation table to determine the port number to use.

Client-server model

A **client-server** model is where the workstations in any network design use the server to provide a service. The many types of server include:

- Email server – provides client email handling
- Web server – handles website hosting and client website traffic
- File server – contains network files, including programs and data
- Database server – stores database, and handles client editing, searching and interaction
- Print server – handles client printing by buffering and ordering individual print tasks

The basic operation is where the client makes a service request from the server, which then fulfils the request; for example, a web browser at the client computer may access information at any web server in the world.



The print server use printer between sev network (LAN), as s

Further information in Section 9.2 of thi

9.4 – Progress Check

18. Explain the difference between public IP addresses and private IP addresse
19. Explain how network address translation operates, and describe two benef (6 marks)

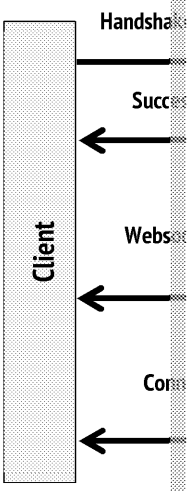
Websocket protocol

Application program interface (API) is a set of function calls that enable communication between two programs.

The API consists of a set of rules that allow one application to communicate with another or to move data from one application to another. For example, the web application Google Maps links with a restaurant directory program to display details of restaurants near your current location.

Websocket protocol describes the rules for creating a persistent connection between two networked computers to enable real-time data transfer.

The websocket protocol creates a persistent connection between the client and web server after a successful handshake routine. This connection is full duplex, meaning that data can be exchanged in both directions.



9.4 – Progress Check

20. Describe the function of the websocket protocol. (4 marks)

Create, retrieve, update and delete (CRUD)

The main functions used to control web-based databases are create, retrieve, update and delete – defined by the acronym **CRUD**.

All of the CRUD functions are necessary to create and manage a database.

Structured query language (SQL) is used to control and manage relational databases; it contains equivalent commands to CRUD, as listed in the table shown.

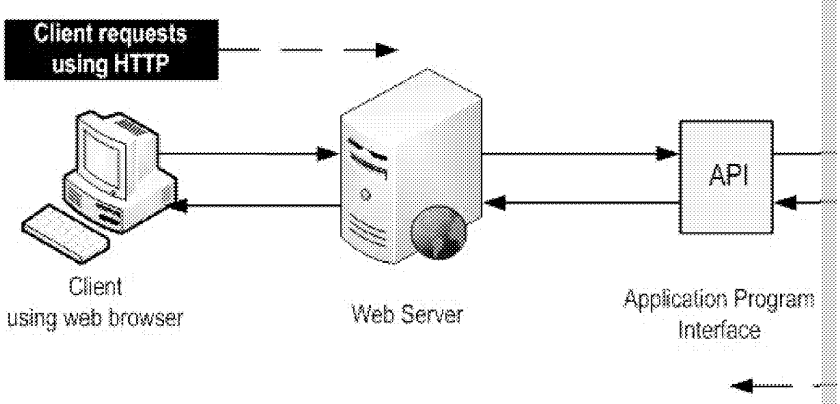
CRUD
Create
Retrieve
Update
Delete

Representational state transfer (REST)

Representational state transfer (REST) is a methodology for implementing web-based databases. It makes use of hypertext transfer protocol (HTTP) commands to perform the CRUD function necessary to create and manage a database.

The table on the right shows the mapping between the basic CRUD functions, the SQL database control functions and the HTTP communication functions.

CRUD
Create
Retrieve
Update
Delete



The schematic diagram above shows the communication route using a **REST** methodology stages:

- The client uses a web browser to send a request to the database.
- The database service request query is identified using its **URL** (uniform resource locat
- The **API** (application program interface) is used to link the client to the database and
- The service request and associated data are transmitted using **HTTP** (hypertext transf
- The database server response is in the form of **XML** (extensible markup language) or J

JavaScript object notation versus XML

Data objects can be formatted for transfer across servers and web application using JSON

XML (extensible markup language) is a markup language based on tags, similar to H around a network and also for data storage.

JSON (JavaScript object notation) is a text-based, human-readable data format that is network.

XML Example	
...>	{
<Name>AQA </Name>	"Name"
<Phone>0161 953 1180</Phone>	"Phone"
<Postcode>M15 6EX</Postcode>	"Postcode"
<....	}

XML and JSON compared

The simple examples above indicate the differences between the format of XML and JSON shown in the list below.

- **Human readability** – easier to read in JSON as it is written as a list of objects and the cluttered as it is contained within markup tags
- **Parsing** – faster to parse in JSON as it is clearly defined as a list objects and their valu its value have to be removed from their tags
- **Code creation** – JSON creates less code for a given data set than XML, and the coding is simpler than XML
- **Data types** – XML can be used to create any data type required where this data struct whereas JSON may have too limited a range of data for all applications

Thin-client versus thick-client computing

Thin-client computers are low-specification devices; they have little processing powe to provide resources, such as processing power and storage for main programs and da

The thin-client computer doesn't require any additional software to be downloaded; it typ browser. The advantages and disadvantages of using the thin-client model are listed belo

Thin-client model advantages	Thin-client model disad
Improved security as client access rights can be managed to reduce access to vulnerable files on the server	A high bandwidth netwo poor response time duri
Network administrator can back up all system data more easily and control clients activities	It is expensive to purcha server capable of operat
Software and hardware can be configured and updated from the server	Server failure or inacces being affected

Thick-client computers are fully functional computers, so they can operate without be server. In a thick-client network, the server can give the client additional processing p to software that is installed on the server and run from the client machine.

Thick-client model advantages	Thick-client model disa
Improved performance for thick-client users, as software applications are processed locally on the client device	Less security as clients c the Internet directly
Thick-client computers can run stand-alone from the network where necessary, minimising the impact of server failure or the network being inaccessible	Further tasks for networ software need to be con client machine
Thick-client software offers additional features and customisation which improve the usability of the application	Additional costs incurre be a higher specificatio

9.4 – Progress Check

21. Define the term 'representational state transfer' (REST) and describe the c web-based database. (6 marks)
22. Compare the use of XML and JSON in terms of parsing and human readabil
23. Define the thin client, and describe three advantages of using a thin-client
24. Define the thick client, and describe three advantages of using a thick-clie

10.1 FUNDAMENTALS OF DATABASES

Databases

A database can be described as 'a persistent organised store of data that is used on a computer system'. Persistent means that it is saved to a file so that it is non-volatile and so can be accessed again.

Flat file database

A flat file database can be created in a word processor or spreadsheet as it is only composed of one file or table.

In the spreadsheet example below a single table database is used to keep a record of the balance accounts for a small business.

In a flat file database, each **row** of the table is known as a **record** and each column is known as a **field**.

	A	B	C	D	E	
1	Customer	Title	Initials	Name	Address 1	Addre
2	1	Dr	M.G.	Featherst	1 Abbey Hey Lane	GORTO
3	2	Mrs.	R.	Camfield	1 Angle Street	RUGBY
4	3	Dr	R.	Davison	1 Byron Street	BURNL
5	4	Mr.	H.W.	Kinghorn	1 Cayton Drive	WIGST
6	5	Mr.	C.	Tyrkas	1 Crowland Avenue	BIRMI
7	6	Mr.	G.S.	Arnold	1 Gargrave Road	SKIPTO
8	7	Mrs.	K.	Harland	1 Hezelmere Close	BARNA
9	8	Dr	D.J.	Austin	1 High Holme Road	LOUTH
10	9	Ms	D.B.	Flett	1 Hill House Farm	PRESTO
11	10	Mr.	D.	Adams	1 Hilton Close	HARLO
12	11	Ms	A.	Malton	1 James Reckitt Avenue	HULL
13	12	Mrs.	G.	Irons	1 Juniper Avenue	DORKI
14	13	Mrs.	C.	Archer	1 Kellet Road	CARNF
15	14	Ms	A.	Perdemo	1 Lennhurst Avenue	LEEDS
16	15	Mr.	P.	Renny	1 Lightfoot Terrace	HAYW

Mail Order Database

Relational databases

A **relational database** is managed using a relational database management system (RDBMS). It is a database that comprises more than one table, where tables that share a relationship are joined by linking a primary key in one table to a foreign key in another.

The **primary key** in a table is a unique identifier and forms the index for that table. Typical examples of unique identifiers are car registration numbers, passport numbers or National Insurance numbers. AutoNumber data type can be used when creating a table to ensure that a unique identifier is defined.

The **foreign key** usually has the same field name as the primary key, but is not a key field. It is used to link with the primary key of another table to form a relationship between the two tables.

The **composite primary key** is used in a table where two columns are used to form a combined key field. It is necessary for both columns to be combined to form a unique reference.

Entity and relationship

An entity is an object that data can be stored about; typical examples are customers, products and sales. In a relational database each entity modelled is represented by a table.

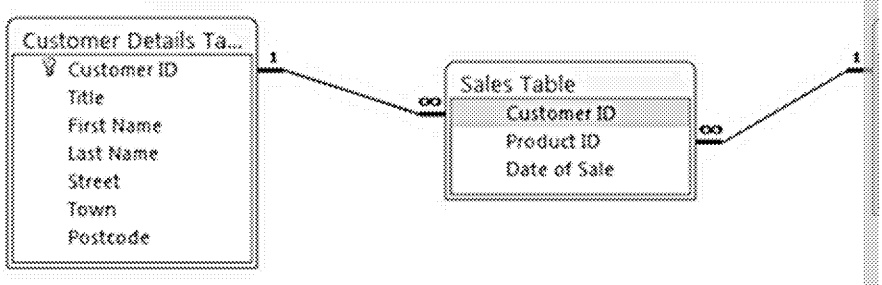
The advantage of using a relational database is that data redundancy is reduced as linking the data tables reduces the duplication of data. This makes it simpler to keep information up to date and increases the accuracy and consistency of data. The most common type of relationship defined in a relational database is **one to many;** typical examples are:

- One teacher can have many students
- One student can be enrolled on many courses
-

Attributes are the details about an entity in a database. For example, the customer details table shown below has the following attributes:

CUSTOMER DETAILS: Customer ID, Title, First Name, Last Name, Street, Town, Postcode

An efficient solution for the customer sales relational database can be created from three ta
relationship diagram below.



The entity relationships are set up as follows:

1. **Customer details** table is related **(one to many)** with the **sales** table
2. **Mobile devices** table is related **(one to many)** with the **sales** table

The advantage of this structure is that customer details only have to be entered once, and t
device only has to be entered once into the mobile devices table.

10 – Progress Check

1. Explain the difference between a primary key and a foreign key in a relati
2. Explain the difference between a flat file and relational file database. (4 r
3. Describe the advantage of using a relational database. (2 marks)

Normalisation

Normalisation is the formal process involved in the design of an efficient database; this is a
are created to cause a reduction in data dependency and data redundancy.

First normal form is where tables contain no repeating attributes or groups of attributes.

Second normal form is where tables contain no partial key dependencies.

Third normal form is where tables contain no non-key dependencies.

The single table **flat file database** for a sports club is shown below in un-normalised form.

MemberID	FirstName	LastName	CourseID	CourseName	Tra
1564A	Jon	Lane	YOGA/A CT Swim/A	Advanced Yoga Circuit Training Advanced Swimming	JT DW CK
5472G	Helen	Smith	P/B Swim/A	Beginners Pilates Advanced Swimming	LS CK

The **normalised** database for the sports club is shown below.

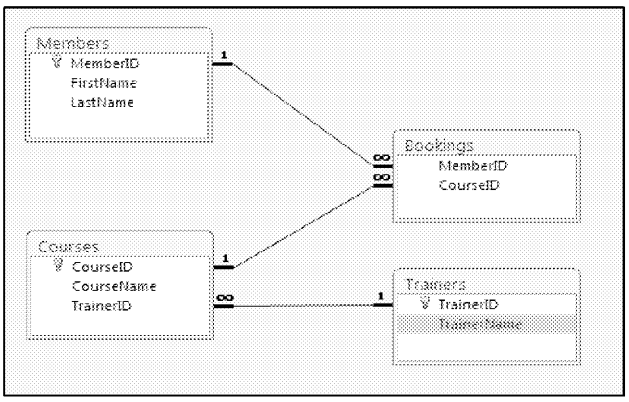
Four tables are created to normalise the sports club; the primary keys are underlined.

MEMBERS (MemberID, FirstName, LastName)

COURSES (CourseID, CourseName, TrainerID)

BOOKINGS (MemberID, CourseID)

TRAINERS (TrainerID, TrainerName)



The entity relationship diagr

- one member can have ma
- one course can be booke
- one trainer can take man

Entity relationships are set u

1. **Members** table is relat
2. **Courses** table is relate
3. **Trainers** table is relate

10 – Progress Check

4. Briefly define the following terms:
   (a) Normalisation (2 marks)
   (b) First normal form, second normal form and third normal form (3 marks)

Structured query language (SQL)

Relational database management systems (RDBMS) support the use of structured query lang
maintenance purposes.

Using SQL to create database structure

The following examples of simple SQL statements are related to a Sports Club:

CREATE DATABASE Sports Club

This command creates an empty database named Sports Club.
The next step is to add tables to the database.

CREATE TABLE Customers

(CustomerID INT NOT NULL, FirstName VARCHAR(50), LastName VARCHAR(50), PR

This command has created a table named Customers with CustomerID as a primary
a null value. The table structure is shown below.

CustomerID (Primary Key)	FirstName	LastName

The DROP command

This can be used to delete tables or a database; for example:
DROP DATABASE Sports Club
DROP TABLE Customers

Add/Modify data

INSERT INTO 'Sports Club'. 'Customers' ('CustomerID', 'FirstName', 'LastName') **VALUES** ('1
The insert statement adds a row to the Customers Table and enters data into each f

CustomerID	FirstName	LastName
1	Jane	Wilson

UPDATE 'Sports Club'. 'Customers' SET 'LastName' = 'Marriott' **WHERE** 'Customers'. 'Custom
The Update function can be used to edit data in a table row that has already been
In this case, the LastName field has been edited as shown below.
The keyword SET identifies the field being updated.

CustomerID	FirstName	LastName
1	Jane	Marriott

Further rows (or records) are now inserted into the table using the insert comman

CustomerID	FirstName	LastName
1	Jane	Marriott
2	Jon	Brown
3	Kate	McPherson
4	Steve	Davies

DELETE FROM Customers WHERE CustomerID = 2

In this case, the delete function removes the row or record where CustomerID=2.

CustomerID	FirstName	LastName
1	Jane	Marriott
3	Kate	McPherson
4	Steve	Davies

Extracting data from tables

The SELECT command can be used to extract data from a database.

Extract all records from a table

SELECT * FROM 'Customers'

The command above will extract all records and attributes from the Customers tab

1	Jane	Marriott
3	Kate	McPherson
4	Steve	Davies

Extract one record from a table

SELECT * FROM 'Customers' WHERE 'CustomerID' = 4

The command above will only extract the record where CustomerID = 4.

4	Steve	Davies

Extract more than one record from a table

SELECT * FROM 'Customers' WHERE LastName LIKE 'M%'

1	Jane	Marriott
3	Kate	McPherson

SQL and relational databases

The Sports Club database has been further developed to contain a table of Customers and a t

Customers Table

CustomerID (Primary Key)	FirstName	
1	Jane	
2	Jon	
3	Kate	
4	Steve	
5	Mario	

Sessions Table

Trainer	Cost	Date
Zak	25.00	July 1
Sally	30.00	July 12
Liz	27.50	August 1
Zak	25.00	September 9
Liz	27.50	July 14
Sally	30.00	July 29

SELECT Customer.FirstName, Customer.LastName, Sessions.Date, Session.Cost FROM Cus
WHERE Sessions.Cost < 30.00 AND Customers.CustomerID < 4

This query is based on the two tables Customers and Sessions.

It has extracted the FirstName, LastName, Session Date and Session Cost where th the CustomerID was less than 4.

FirstName	LastName	Date
Jane	Marriott	July 1
Jon	Brown	July 14

INNER JOIN

An inner join between two tables will return the rows where there is a match between the t
Customers and Sessions tables from above:

SELECT Sessions.Trainer, Customers.LastName, Sessions.Date
FROM Sessions
INNER JOIN Customers
ON Session.CustomerID = Customers.CustomerID

This will return the Session Trainer, Customer LastName, Session Date for CustomerID = 1,2

Select query logical operators

Different logical operators that can be used to filter data in SQL include:

AND	Displays result if condition 1 AND condition 2 are TRUE
OR	Displays result if condition 1 OR condition 2 is TRUE

10 – Progress Check

5. An online book shop has created a relational database known as BOOKS4U. It
Publisher table.

Books

BookCode	Name	UnitCost	PublisherCod
271DEC	A2 Computing	19.50	137
56GCSE	GCSE ICT	17.95	94
980UUT	GCSE Physics	16.75	94
GG77WS	AS Biology	23.50	228
9494TT	A2 Biology	23.50	137
TGF67R	GCSE Music	15.75	137

Publisher

PublisherCode	Name	We
137	Thornes	www.thorn
94	Whitchurch	www.whitchurch
228	Masters	www.ma

a) Write out the SQL to create the **Publisher** table. (5 marks)

b) List the results you would obtain from running the following SQL query (4

```
SELECT Books.Name, Books.UnitCost, Publisher.Name
FROM Books, Publisher
WHERE Books.UnitCost   13.0 AND Books.UnitCost   18
```

c) Write an SQL statement to add the following data into the **Books** table (3

BookCode	Name	UnitCost	PublisherCod
177TRV	GCSE Chemistry	19.99	137

Client–server databases

The client–server database model has become one of the central ideas of network compu
maintained on a server and the client is considered to be a user who accesses the databas
the network. The client–server database is a multi-user system that allows several clients
simultaneously.

The client–server database uses a database management system software application to c

Database management system (DBMS)

A database management system (DBMS) is a software application designed:

- to interact with database users
- to capture, extract and analyse data
- to interact with other software applications

Database capture and manipulation of data

DBMS software is used to create a database, capture, select and retrieve data, as well as e
applications; DBMS provides the following:

- A database structure can be created including linking tables to form relationships a
the elements of the database. Many DBMS systems automatically create documenta
- **Tables** are used to store data which can be captured by a **data entry form** or by imp
a range of formats, such as CSV files.
- **Queries** are mainly used to retrieve specific data from a table or tables; where this d
a complex query will process the data into a single datasheet. Queries also let you a
just the records you want and often these results are used as a record source for for
- **Reports** are used to summarise and present the data that is in the tables. A report i
such as 'list details for each customer account this month'. Each report can be forma
the database in the most readable way possible and can be outputted to the printer
application or program.

Data management and administration

DBMS software is used by the database administrator to maintain the system as follows:

- Provides for a centralised automatic backup of the system.
- Assign different types of database user with associated access rights.
- Provide logon and password facilities for users.
- Update of DBMS programs and development of associated software tools

Program-data independence

In a DBMS the data is separated from the applications that access it, so programs work ind
advantage of this is that database administrators can modify the software tools that contr
remain unchanged by these programs.

There are many commonly used DBMS systems including Oracle, dBase, MS Access and My

10 – Progress Check

6. List four features that a DBMS provides the system administrator with to m
7. Explain the benefits of program-data independence in a DBMS. (2 marks)

Concurrent access issues for client–server databases

Concurrent access can cause issues where data can be lost if two or more clients attempt to
at the same time.

The following techniques can be used to manage this problem:

- **Record locking** – with this technique, a record is locked when it is being accessed by
prevents additional users from editing and saving the record until the original user is
transaction.
- **Serialisation** – this technique only permits one transaction at a time to take place wi
database.
- **Timestamp ordering** – this approach timestamps the start time of each database tra
system clock. The oldest timestamp transaction takes priority and is executed first wi
on the same record.
- **Commitment ordering** – in this case, the order of operation of concurrent transactio
the precedence of the particular command requested; for example, some commands
so they are, therefore, executed before older timestamp transactions.

10 – Progress Check

8. Compare record locking and commitment ordering as techniques that could
access to databases. (4 marks)

11.1 BIG DATA

Big data is a relatively new term and it refers to large data sets that are too difficult to store complex to easily analyse. Big data is based on the following characteristics:

- **Volume** – organisations gather and store large amounts of data; the amount of data c is big data.
- **Velocity** – data streams are collected in a near-to-real-time fashion, making the proce
- **Variety** – data comes in a wide range of formats, such as text, audio, video, images, a

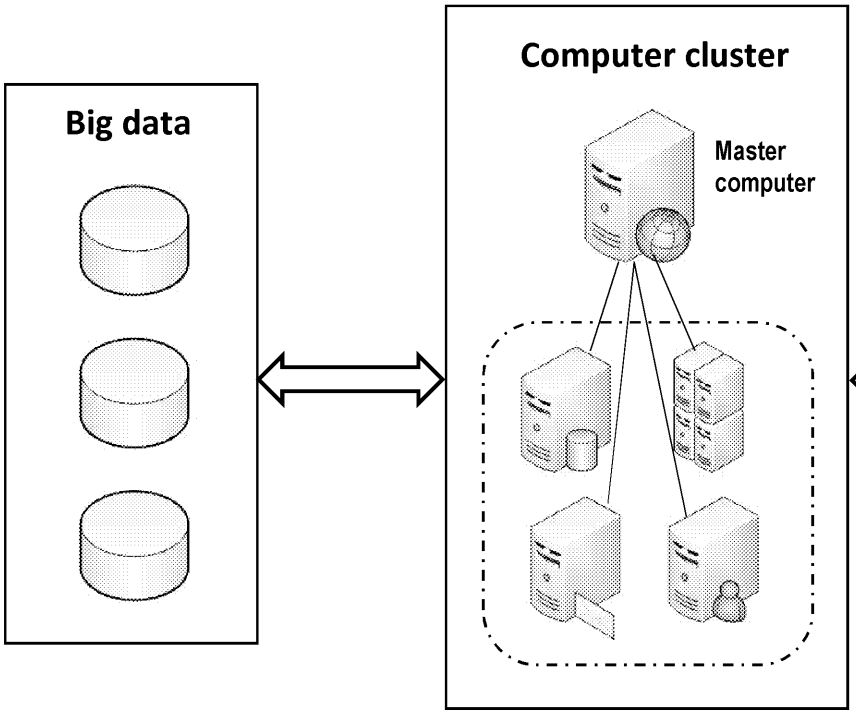
The ease with which data can be organised gives an indication of its ability to be analysed, s structured or unstructured, as outlined below.

- **Structured data** – can be defined as data that is appropriate to be entered into a relat format; consequently, this data can be analysed and queries can be used to extract us
- **Unstructured data** – can be defined as data that is difficult to organise and is not app and column format. Machine learning data analysis techniques are used on unstructur and extract useful information in a cost-effective manner. Data analysis is difficult on formats used.

Distributed processing

When data is too big to be processed on a single machine, the processing is distributed acro distributed processing.

The block diagram below shows a typical distributed system where the computer cluster sha master computer makes use of specialist software to control each networked computer as th



Functional programming

A **function** is a subroutine that carries out a set of instructions and returns a value.

Functional programming is a paradigm based on the use of functions to determine variables similar to mathematical expressions to calculate the value of a variable.

In functional programming, data structures are **immutable**, meaning that the function only c data at the time the function is executed. Therefore, new data structures are created rather t structure, so a function to update the value of an array will create a new array with updated v

This is not the case in procedural languages that are mutable and have the **side effect** that c impact on how the program is executed. Functional programs are immutable so do not suffe

Functional programming also supports:

- **Statelessness**, which means each function is calculated with no reliance on any data o function inputs; there is no dependence upon events that happened previously in a pr
- **Higher-order functions** are functions that either take other functions as an input (or a output.

Due to immutability and statelessness, functional programming objects have a high degree o ability to be shared between multiple processors; this is essential in distributed processing a ensure that the system performs correctly each iteration.

Functional programming has the advantage of being concise and efficient. Consequently, it is is especially useful in distributed processing, where a specialist software package can be use to the various processors.

Fact-based model for representing data

The fact-based model is a method used for storing data; it has the advantage that data can b termed facts, where each fact within a fact-based model captures a single piece of informati

The following example is based on some simple facts from a sixth-form college setting:

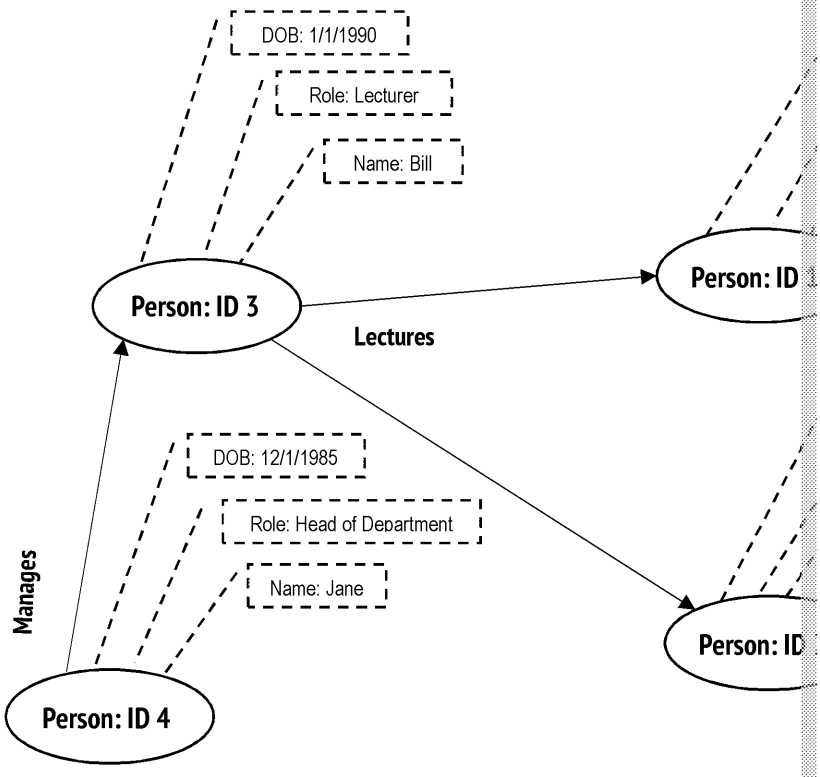
a) Jack and Chloe are both students studying A Level Computer Science.
b) Bill is a lecturer responsible for A Level Computer Science.
c) Jane is Head of Department and manages Bill.

Graph schema for modelling data

The core components used in a graph schema are:

1. **Nodes**, which are the entities within the dataset
2. **Edges**, which are the links and the associated relationships between nodes; edges are directed or undirected
3. **Properties**, which are the information stored within each entity; details of properties a

The facts from the sixth-form college example are shown below in a graph schema.



The facts are stored in the graph schema using fields: DOB, Role and Name.

11– Progress Check

1. Describe the main characteristics of big data. (3 marks)
2. Compare the terms 'structured data' and 'unstructured data'. (4 marks)
3. Define the following terms:
   a) Functional programming (2 marks)
   b) Immutable data structure (2 marks)
   c) Statelessness (2 marks)
   d) Higher-order functions (2 marks)

TOPIC 12 – FUNDAMENTALS OF FUNCTIONA

12.1 FUNCTIONAL PROGRAMMING PARADIGM

Variety of programming paradigms

There are many programming languages that are designed based on a system of ideas kno paradigms; below are brief descriptions of the four main programming paradigms required Science specification.

Imperative paradigm	Programming languages based on the imperative paradigm make u which are written to and, therefore, change the state of computer be translated into efficient machine code. Procedural programming is an imperative language and is dealt w
Functional paradigm	The functional paradigm uses programming languages that evalu than the imperative method where values are assigned to variable determined by calling functions. Functional programs are used to solve problems in complex struct and it is, therefore, easier to determine errors.
Logic paradigm	The logic paradigm is especially useful in solving problems that in knowledge from declared facts and their rules. Prolog is a declarative logic programming language that is widely expert system applications; it is useful for rule-based systems. Ty diagnosis expert systems, and in banking to determine investmen
Object-oriented paradigm	The object-oriented paradigm is based on data structures known a of a class which are grouped into a class hierarchy. Object-oriented programming languages are dealt with in more d

Function type

A **function** can be defined as a relation between input values from the domain to a set of in which each input is related to exactly one output.

A function can be written as **f: A** $\longrightarrow$ **B** where

The symbol $\longrightarrow$ means 'maps to'

The set A is the domain of **f** – the domain contains the input values for the func

The set B is the codomain of **f** – the codomain contains the set of output values

Function example:

f(x) = x^2 + 1 gives the following results:

Input	Relationship	Output
0	$x^2 + 1$	1
1		2
2		5
3		10

First-class object

A **first-class object** is a language object which supports the operations normally available

- appearing in expressions
- being assigned to a variable
- being used as an argument for a function
- being returned as an output from a function call

In many programming languages, first-class objects can consist of the following: integers, strings.

Functional programming makes use of higher-order functions and first-class objects, since another function and as the result of a function call.

Function application

Function application is the process of providing a function with an input value from its do codomain.

An earlier example function **$f(x) = x^2 + 1$** can be evaluated by inputting a single value
Using value A = 2
Gives **$f(x) = 2^2 + 1 = 5$**

Any value from the domain can be used in the application of a function.

Partial function application

Partial function application can be applied to a function that requires more than one argu applying the function with some but not all of the arguments needed. A new function is th of the function.

For example, adding three integers together can be performed as a partial function ap
Function **add3integers(x, y, z)** will process as follows:
add (x, y) ⟶ (z)
so the function **add3integers(x, y, z)** will return (x + y + z)

Composition of functions

Composition of functions is the process of combining two functions by applying the result

This technique is widely used in functional programming, where complex functions can be functions.

The composition of two functions **f** and **g** is written as **$g \circ f$**, which gives a new composite fu

For example, given the following functions:
$f(x) = (x - 5)$ and **$g(y) = y^2$**
$g \circ f = (x - 5)^2$
Therefore, function **f** is applied first, and then function **g** is applied to the result.

12.2 WRITING FUNCTIONAL PROGRAMS

Functional language programs

The **map function** applies a given function to each of the elements in a list to form anothe
The map function example using Haskell is based on squaring integers in the list [1, 2, 3, 4
The first task is to define a **square function** to square one integer input.

```
square :: Int → Int
square x = x * x
```

The **map function** can then be used with the square function to calculate the output for ea

```
map square [1, 2, 3, 4, 5, 6]
```

The map function goes through each element of the list and applies the square function, g

```
[1, 4, 9, 16, 25, 36]
```

Filter function is a higher-order function that processes a list or data structure to create a
match the specified criteria.

Even number filter example
The filter function example using Haskell is based on finding even numbers in the list [1, 2

```
filter even [1, 2, 3, 4, 5, 6]
```

In the statement, the predicate 'even' returns or filters out all the numbers in the argumen

```
[2, 4, 6]
```

Logical statements can be used in functional programming to filter data, as shown in	
filter (not . even) [1 .. 12] **[1, 3, 5, 7, 9, 11]**	returns all the odd numbers in argument
filter (<5) [1, 7, 12, 3, 6] **[1, 3]**	returns all the numbers in argument tha
filter (==7) [1, 7, 12, 3, 6] **[7]**	returns all the numbers in argument tha

Reduce or fold function is a method that can be used to reduce a list to a single value by c
function.

The following example traces the fold function to sum all the elements of a list using the

List	Result	Explanation
[1,2,3,4,5]		Original list
[2,3,4,5]	1	Fold left, by removing the left-hand element fro
[3,4,5]	1 + 2 = 3	Remove the next element (2) from the list and a
[4,5]	3 + 3 =6	Remove the next element (3) from the list and a
[5]	6 + 4 = 10	Remove the next element (4) from the list and a
[]	10 + 5 = 15	Remove the last element (5) from the list and a
Function completed – all elements of list [1,2,3,4,5] have been added.		

12.3 LISTS IN FUNCTIONAL PROGRAMMING

List processing

A **list** is a data structure consisting of a list of data elements that are of the same data type identifier and the data elements stored can be integers, real numbers, characters or text st

A list data structure contains the following:

- **Head** – this is the first element of the list.
- **Tail** – this is all the other elements of the list apart from the head.
- **Length** – this is the number of elements in the list.

Empty list
A list with no elements is termed an empty list and is shown using the symbols **[ ]**

Haskell head / tail defined
In Haskell, a list can be written in the form of **head : tail**

Therefore, the list **[6, 4, 9, 12]** can be written as **6 : [4, 9, 12]**
where **6** is the head of the list and **[4, 9, 12]** is the tail

List operations

The standard processes that can be carried out on lists are shown in the table below:

Process	Description	
Return head of list	Returns the first element of the list (1) using the **head** command in Haskell	**hea** **1**
Return tail of list	Returns the all the other elements apart from the head (2, 3, 4, 5, 6) using the **tail** command in Haskell	**tail** **[2,**
Test for empty list	Returns **True** if the list being checked is empty using the **null** command in Haskell	**nul** **Tru**
	Returns **False** if the list being checked is not empty using the **null** command in Haskell	**nul** **Fal**
Return length of list	Returns how many elements are contained in a list (6) using the **length** command in Haskell	**len** **6**
Constructing lists	Assign an **empty ([ ])** list using the **let** command in Haskell, as shown in the example	**let** **em** **[ ]**
	Assign a list (**[5, 6, 7, 8]**) using the **let** command in Haskell, as shown in the example	**let** **myl** **[5,**
Prepend an item to a list	Add a new element **[1]** to the beginning of the list **[5, 6, 7, 8]**, as shown in the example	**[5,** **let** **myl** **[1,**
Append an item to a list	Add a new element **[9]** to the end of the list **[5, 6, 7, 8]**, as shown in the example	**[5,** **let** **myl** **[5,**

12 – Progress Check

1. Describe the functional program paradigm. (3 marks)
2. Define the term 'function'. (2 marks)
3. Evaluate the function f(x) = 2x2 + 5 where x =3. (1 mark)
4. List the operations that first-class language objects support. (4 marks)
5. Explain the term 'composition of functions'. (2 marks)
6. Determine the composite function (g o f) where f(x) = (14 + x) and g(y) = y
7. Define the following functions
   1. Map (1 mark)
   2. Filter (1 mark)
   3. Fold (1 mark)
8. Trace the fold or reduce function to find the product of the list [1, 2, 3, 4,
9. Determine the head, tail and length of the following list: [9, 11, 17, 18, 2
10. Determine the result of prepending [7] to the list [9, 11, 17, 18, 27, 28, 2

ANSWERS

Topic 5 – Data representation

5.1 N is the set of natural numbers used for counting, e.g. 2 apples (1), whereas Z is th
includes the natural numbers and their negative inverses, e.g. -2, -1, 0, 1, 2. Intege

5.2 Convert binary 1110 0111 to decimal. (2 marks)

128	64	32	16	8	4	2	
1	**1**	**1**	**0**	**0**	**1**	**1**	

So 128 + 64 + 32 + 4 + 2 + 1 = **231_{10}**

5.3 Convert decimal 101 to binary. (2 marks)

128	64	32	16	8	4	2	
0	**1**	**1**	**0**	**0**	**1**	**0**	

5.4 Convert hexadecimal 3FA to decimal. (2 marks)
First convert to binary, so $3FA_{16} = 001111111010_2$.

3				F				
8	4	2	1	8	4	2	1	
0	0	1	1	1	1	1	1	

Then use the table to convert to decimal.

512	256	128	64	32	16	8	4	
1	1	1	1	1	1	1	0	

So 512 + 256 + 128 + 64 + 32 + 16 + 8 + 4 + 1 = **1018_{10}**.

5.5 Convert decimal 7012 to hexadecimal. (2 marks)
(1) 7012 decimal is converted to binary; therefore, $1101101100100_2 = 7012_{10}$.

4096	2048	1024	512	256	128	64	32	16	8
1	1	0	1	1	0	1	1	0	0

(2) Split the binary number into nibbles and convert into hex to give **$1B64_{16}$**.

5.6 Convert binary 0011 1111 to hexadecimal. (2 marks)
- Treat the 8-bit binary code as two hexadecimal nibbles: 0011 and 1111
- which converts to 3 and F
  So, **$00111111_2 = 3F_{16}$**.

5.7 Convert hexadecimal B7 to binary. (2 marks)
- Convert the two hexadecimal nibbles separately using the table, so $B_{16} = 101$
- Join them together to form an 8-bit binary number.
  So, **$B7_{16} = 10110111_2$**.

5.8 A kibibyte (KiB) is a unit used for digital information (1), where 1 kibibyte = 1024 by

5.9 Add the following unsigned binary numbers: 00000101 and 11000100. (2 marks)

	0	0	0	0	0	1	0	1
	1	1	0	0	0	1	0	0
Sum	1	1	0	0	1	0	0	1
Carried	0	0	0	0	1	0	0	

So 00000101 + 11000100 **= 11001001 binary**

5.10 Multiply the following unsigned binary numbers: 00010101 and 00000101. (2 mar

		0	0	0	1	0	1	0	1
		0	0	0	0	0	1	0	1
		0	0	0	1	0	1	0	1
0	0	0	1	0	1	0	1		
		0	1	1	0	1	0	0	1

Carry 1 1

00010101 x 00000101 = 01101001 Binary

5.11 Subtract 24 – 12 using two's complement. (2 marks)
24_{10} = 0001 1000$_2$ and
12_{10} = 0000 1100$_2$ which is (1111 0011) + 1 = **1111 0100$_2$** in two's complement form

	0	0	0	1	1	0	0	0	24
	1	1	1	1	0	1	0	0	-12
Sum	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	24 – 12 = 12
Carry	1	1	1	0	0	-	-	-	So **0001 1000$_2$ – 0000 1100$_2$ =**

5.12 Convert fixed-point binary number **1001111100.1010** into decimal. (3 marks)
First write the binary numbers into a table in the correct order.

512	256	128	64	32	16	8	4	2	1	.	1/2
1	0	0	1	1	1	1	1	0	0	.	1

Then add the decimal numbers where 1 is shown:
1010000111. 10010$_2$ = 512 + 64 + 32 + 16 + 8 + 4 + 0.5 + 0.125 = **636.625**
Alternatively 512 + 64 + 32 + 16 + 8 + 4 + $\frac{1}{2}$ + $\frac{1}{8}$ = 636$\frac{5}{8}$

5.13 72.465 rounded to four significant figures = 72.47 (1)
Rounding error = 72.465 – 72.47 = -0.005 (1)

5.14 (a) Absolute error is the difference between the theoretical exact value calculat
processed computed value to be stored. (1 mark)
(b) Find absolute and relative errors for a computed value of 0.082 and an exac
Absolute error = | exact value – computed value | = | 0.0766 – 0.082 | = 0
Relative error = Absolute error / exact value = 0.0054 / 0.0766 = 0.070496

5.15 (a) Range is the set of all numbers that can be represented using a specific num
associated with word length and the maximum number of significant digits t
(b) Fixed point binary numbers have more precision than floating point number
a wider range (1).

5.16 **Convert floating point number 0110000000 111001 to denary:**
Exponent 111001
Two's complement of exponent is 000111 = -7 in denary
Mantissa is 0.110000000
The binary point needs to be moved seven places to the left, giving 0.000000011
0.000000011 is 1/256 + 1/512 = 3/512 or 0.005859375 in denary
Therefore, binary number 0110000000 111001 is 0.005859375 in denary

5.17 Underflow occurs where the required value is too small to be stored using the nu
overflow occurs where the required value is too large to be stored using the nun

5.18 ASCII is a 7-bit character set which offers 128 different characters (1), and many of
controlling peripherals (1), whereas Unicode is a 16-bit character set which offers
includes the character for any writing system in the world (1).

5.19 Even parity is where the numbers of 1s in the data to be transmitted is counted, a
the parity bit is set (1) to 1. In the example below the 7-bit ASCII code for Q is 1010
the parity bit is set (1) to 1.

Parity Bit	ASCII Code for Q					
1	1	0	1	0	0	0

5.20 Analogue to digital converters (ADC) converts an analogue signal that varies conti
signal.

Analogue signals are input into the device in the form of voltage waveforms (1) th
format before they can be read and understood by the computer (1).

Digital to analogue converters (DAC) convert a discrete digital signal (1) into a con
that is outputted from a computer (1). For example, sound outputs from a compu
signals for use by speakers.

5.21 Digital image terms:
(a) Colour depth is the number of bits used for each pixel (1), where 1 bit is black
colours (1).
(b) Resolution is the number of pixels per inch (1) – often termed dpi or dots per
better image resolution (1).
(c) Metadata is included in an image file (1) and gives details of image height, w

5.22 Calculate the memory used in kilobytes for a digital photographic image that is 8,5
with colour depth 24 bpp (bits per pixel) where 1 byte = 8 bits (2).

Total pixels = 8500 * 4020 = 34,170,000
File size (bytes) = total pixels * (colour depth / bits per byte)
= 34,170,000 * (24/8) = 102,510,000
File size (MB) = 102,510,000 / (1,024 * 1,024) = <u>97.76 MB</u>

5.23 Digital sound terms:
(a) Sampling rate is the number of samples taken per second from the analogue
(b) Sampling resolution (or audio bit depth) is the number of bits used to store e

5.24 (a) Vector graphics can be rescaled or resized with no loss of quality (1).
(b) Bitmap images use less processing power than vector graphics (1).

5.25 Lossless compression is where a file can be compressed (1) but the facility exists t
the exact original format (1). Lossy compression is where a file is compressed by re
file size (1), so it is not possible to create an exact copy of the original file (1).

5.26 Encryption is used to make stored data more secure from hackers by making it un
the key to decrypt or decode it (1). Cryptography is the process of creating ciphert
as encryption) and turning it back to the original plaintext (known as decryption) (1

5.27 The Caesar cipher is a commonly used and simple substitution cipher; using this te
in a message is replaced (1) by a different letter of the alphabet, a fixed position fr

The ciphertext: CU EQORWVGT UEKGPEG that has been encrypted with a Caesar c
the decryption key of a right shift by two places in the alphabet decrypts the mess

Topic 6 – Computer systems

6.1 Software is the actual programs or coded instructions (1) that make the computer
physical parts (1) that make up a computer system (1).

6.2 Programming languages:
(a) Machine code is the set of binary instructions (1) that are used by the CPU to
(b) Assembly language is a low-level computer programming language (1) which
instruction is one machine operation (1).
(c) High-level language is a computer programming language (1) based on natur
notation (1).

6.3 The advantages of machine code and assembly languages compared to high level
- Programming in low-level code can create faster and more efficient code as
performance level of the created code (1); with high-level programming ther
create optimised code (1).
- Low-level language code is memory efficient due to the lack of abstraction in
level languages (1).

The disadvantages of machine code and assembly languages compared to high lev
- It is difficult to learn to program in low-level languages whereas high-level la
training options (1).
- High-level code can be self-documenting which makes it is more understand
maintenance and debugging (1)
- Machine-code and assembly programs are specific to a limited range of proc
be compiled to run on a wide range of processors (1).

6.4 Source code is the language instructions that have been written by the computer
cannot run or execute the source code directly (1).

Object code (or executable code) is translated from the source code (1) using an a
instructions that can be understood and executed by the computer (1).

6.5 The assembler translates this source code into machine code that the computer c

The advantage of using assembly language is it is an efficient low-level language (1
has a one-to-one relationship with machine code (1).

The main disadvantage of using an assembly programming language is that it is co
programming time and expertise (1).

6.6 A software application called a compiler converts the source code to object code

The main advantage of using a compiler on high-level language code is that an exe
runs without the need of the source code (1).

The disadvantages of this method are that the compilation of a large program tak
any errors in the source code need to be corrected before an executable file can b

6.7 Interpreter software normally executes the source code directly; this avoids the n

The advantage of using an interpreter is that during development the programme
which can be tested without going through the time-consuming process of compi

The disadvantage of using an interpreter is that it needs to be loaded on the targe
efficient machine code at runtime (1). Additionally, the source code is available to
translation method takes longer than a compiled program to run (1).

6.8 (a) S = 0 C = 1 (b) S = 1 C = 0

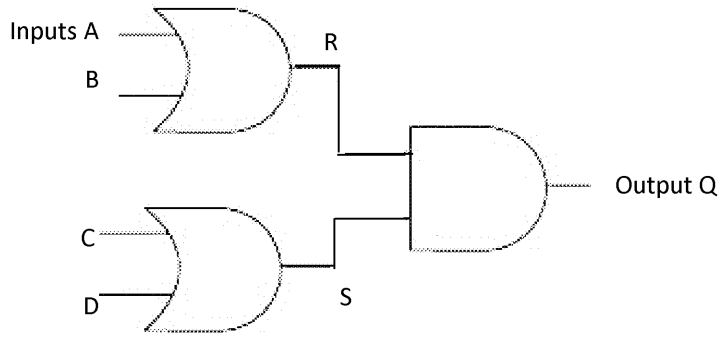
6.9 (a) S = 1 COUT = 1 (b) S = 0 COUT = 1

6.10 A flip flop is an electronic circuit that has two stable states (1) and can be used as a
data (1). A D-type flip flop changes state with each clock pulse (1), so data is delay

6.11 D-type flip flops have a data input and the clock input (1). The outputs are Q, whic
and the inverse of Q (1).

6.12 Use the complex logic diagram to work out the outputs for various values of A, B a
(a) When A = 0 B=1 C = 0 then R = 1, S = 0, T= 0 (3 marks)
(b) When A = 0 B=0 C = 1 then R = 0, S = 1, T= 1 (3 marks)
(c) When A = 1 B=1 C = 0 then R = 1, S = 0, T= 0 (3 marks)
(d) When A = 1 B=1 C = 1 then R = 1, S = 0, T= 0 (3 marks)

6.13 Logic circuit for the Q = (A OR B) AND (C OR D) (3 marks)



6.14 Simplify $\overline{A}$.B.C + $\overline{A}$.C (3 marks)

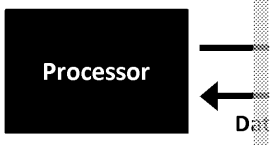
$\overline{A}$.C (B + 1)	Take common terms outside of brackets
$(B + 1) = 1$	So B can be removed
$\overline{A}$.C (1)	Remove bracketed 1
$\overline{\boldsymbol{A}}$**.C**	Final answer

Topic 7 – Computer organisation and architecture

7.1 Computer architecture terms:
(a) The central processing unit (CPU) processes the data in a computer system (
sorting and searching data, performing calculations, logical decision-making
devices (1).
(b) Main memory or immediate access store (1) is storage for program instructio
the CPU (1).
(c) The address bus is used to specify a physical address in main memory (1) and
written into that address is communicated via the data bus (1).
(d) The control bus manages data processing (1) so, for example: by sending a si
bus to a memory address or a signal to read data from a memory address (1)
(e) I/O controllers send control signals to connect a system bus (1) to specific I/O
output (write) requests they receive from the processor (1).
(f) Arithmetic logic unit – performs arithmetic and logical operations, such as fi
arithmetic, logical operations (AND, OR, XOR) and shift operations (1). Inputs
accumulator, with outputs routed to one of the registers (1).

7.2 Van Neumann program architecture

The Van Neumann stored program architecture is based on both data and instructions stored in a single memory (1).



Data and instructions are transmitted through a shared data bus (1). Sketch (2).

7.3 A register is a very fast memory location that exists in the processor or the I/O co
General purpose registers are available for the programmer to store temporary d
Dedicated registers are used by the processor to carry out a specific role (1).

7.4 Dedicated registers:

(a) Status register (SR) is used to hold the status of various flags indicating such t
result, carry bit used, overflow error, and interrupt status. The details of the s
dependent upon the actual processor involved (2).

(b) Program counter (PC) is the register that holds the address of the next instru

(c) Memory address register (MAR) holds the address of the current instruction

(d) Memory buffer register (MBR) holds the instruction from the (MAR) and the

(e) Current instruction register (IR) is used to store the instruction that is to be d

7.5 Fetch-execute cycle

Fetch:

1. Program counter (PC) points to next instruction to be fetched (1).
2. Contents of (PC) copied into memory address register (MAR) (1).
3. The instruction in (MAR) is transferred via the data bus to the memory buffe
register (MBR) (1).
4. The contents of the (MBR) are copied to instruction register (CIR) and the
program counter (PC) is updated to address next instruction (1).

Decode:

The instruction in the (IR) is decoded (1).

Execute:

1. The decoded instruction is executed (1).
2. The process is repeated.

7.6 Processor instruction set terms:

(a) Machine code instructions are written in binary code (1) that a processor can

(b) Op-code instructions are the part of a machine code instruction (1) that repr

(c) Operand is that part of the machine code instruction (1) that contains an iten
which the binary data is stored (1).

(d) Instruction set is the set of machine code instructions (1) that the processor
and execute (1).

7.7 Immediate addressing means that the data in the operand is fixed (1); in other word

This is a very fast addressing mode since the data is readily available (1), rather tha
from a memory address, whereas direct addressing, or absolute addressing, mean
to a memory location (1).

A typical example is the instruction ADD (1302) – this instruction could be used to a
location (1302) to the accumulator (1).

7.8

```
        CMP     r1, r2      ; compares value of A with B
        BGT     greater     ; branch if A > B
        BEQ     equal       ; branch if A = B
        MOV     r3, #0      ; set P = 0
        B       end         ; branch to end
greater MOV     r3, #3      ; set P = 3
        B       end         ; branch to end
equal   MOV     r3, #1      ; set P = 1
end     HALT                ; end of code
```

7.9 The clock speed is a key factor in the performance of a computer; it controls the p
well as fetching data in another cycle (1). Clock speed has increased regularly in re
devices run at a clock speed in excess of 2.5 GHz, or 2.5 thousand million times a s
easily be increased by purchasing a faster device (1). However, the faster the devi
additional cooling is necessary to prevent CPU damage.

System performance can be improved by increasing the number of processors; this
core processor (1) A multi-core processor has more than one processor incorporate
a dual-core processor will provide two processors on one chip, which will operate f

Most modern processors use 32-bit or 64-bit word lengths; the performance of a p in word length, providing that the word length and data bus are the same size (1). S 64-bit bus will allow 64 bits of data to be handled in one clock pulse (1).

7.10 RFID readers communicate with RFID tags, or radio frequency identification tags; t such as a bar code; the tag will be programmed with information (1). Each tag has a aerial) that can be used to communicate with a RFID reader or scanner for trackin

The RFID reader transmits a radio signal which is received by the RFID tag and a co is sent to the reader (1). The code is then decoded and translated into digital data t identify the information received (1). These tags can be used for security purposes i on checkouts where they have the advantage of being scanned remotely and are r

7.11 The main secondary storage device on most computers is a hard disk, which consi which have been coated with a special magnetic material, and a series of read/wr surface to access or store the data on the disk (1). Since the data is stored in this m known as a magnetic storage device. Typical internal hard disks supplied with mo the range 500 gigabytes to 10 terabytes (1).

Solid-state disks act in a similar way to a hard drive except they are based on non- controller to manage pages, blocks of data and the complexities of writing. The fla grid that is separated into sections called 'pages', into which the data is stored. A b pages cannot be overwritten individually; the whole block has to be erased before

SSDs perform faster than hard drives and optical drives as there are no moving pa write and access data faster although they are significantly more expensive to pur tend to be smaller capacity than hard disk drives (1).

Topic 8 – Consequences of uses of computing

8.1. Morals are a set of principles (1) that apply to an individual (1), whereas ethics are group to which the individual belongs (1).

8.2. There are many ethnical responsibilities for software engineers and computer scie have at their disposal is not misused. Some of the typical ethical issues to be awar respects the privacy (1) of those users that will be affected by that software (1), to by ethical and lawful means (1), to maintain the integrity of data (1) and to not kno obtained illegally (1).

8.3. The Computer Misuse Act terms
(a) Hacking – the practice of breaking into (1) secure computer systems (1).
(b) Viruses – are programs designed to cause damage (1) to a computer system (
(c) A firewall is used to prevent unauthorised requests from hackers (1) to gain a systems via the Internet (1).
(d) Spyware – programs that run in a computer system (1) to gather information a parties (1).

Topic 9 – Communication and networking

9.1 Synchronous data transmission is a data transmission method where the data sign clock-generated (1) timing signal; this will ensure that the data transmitter and rec network protocols make use of synchronous transmission, where data is sent in pa

Asynchronous data transmission is where a data stream is transmitted at intermit intervals; this method of data transmission is normally adopted for communicatio

9.2 Communication basic terms:
(a) Bit rate is the number of bits that are transferred across a computer networ normally measured in bits per second (bps).

(b) Bandwidth is the speed of a computer network or the maximum rate at whic
normally measured in Mbps (Megabits per second) and basically bandwidth
data that can pass from one point to another in a unit of time (1).
(c) Latency is the term used in a packet switched network to measure the time
a data packet and destination receiving that packet (1).
(d) Protocol simply means a set of rules or standards (1) which computers use fo
(e) Baud rate is the number of symbols (or signal changes) that are transferred a
set amount of time (1).

9.3 (a) A network topology is a way of describing the interconnections (1) and cablin
(b) Physical topology is how a group of computers are physically connected (1), w
network devices communicate with each other (1).

9.4 (a) Physical star topology:
The physical star network topology is based on connecting each workstation
may also be linked to a file server (1).
(b) Fast response time and no problems with data collision (1) as each workstati
(c) All communication takes place via the central hub (1) and if it fails, the whole

9.5 Peer-to-peer networking:
Peer-to-peer networks are different from client–server networks as they do not h
used as servers (1).

Instead, any workstation on the network can load information from the hard disk
workstation, as all workstations have equal status (1).

9.6 Client–server:
(a) The client–server model is where the workstations in any network design us
where the client is a computer or workstation on a typical network and the f
that interacts with the clients (1).
(b) Security policies for access control and associated usernames are managed c
(c) Server failure can cause the whole network to be inoperative (1).

9.7 Networking terms:
(a) Wireless adaptor performs a similar function to a network interface card (NI
adaptor can be built into the computer or it can be a portable device fitted i
(b) Wi-Fi protected access uses encryption protocols (1) such as WPA/WPA2 tha
connection (1).
(c) SSID stands for service set identification; it is a unique 32-character identifie
network (1).
(d) MAC stands for media access control and it is a physical address (1) assigned
manufacturer (1).

9.8 Packet switching is where large data files are broken down into a series of small dat
Internet (1). Each data packet has details of its destination sent in a header (1). The c
sent to the destination computer via a series of separate routes (1). The actual route
by a router (1) which sends the data package via the fastest connection available (1).
the destination computer they are assembled into the large data file that was origin

9.9 (a) Gateways are used where the networks to be connected are of different typ
between them is more complicated. Data that is sent from one network to t
converted from the format that is used (1) on the sending network into the f
network (1). This process is carried out by a gateway.
(b) Devices called routers are used to determine an efficient route (1) for data tr
and to transmit web pages to users throughout the world (1).

9.10 (a) IP address is a number that uniquely identifies every host on an IP network (
(b) Uniform resource locator (URL) refers to the location of a web resource on th
(c) Domain name server translates domain names into their unique IP addresse

9.11 When accessing the Internet, we may type in the URL for a website into the web b to remember (1). The DNS server is then used to find the matching IP address (1), w difficult for humans to remember (1).

For example, the IP address for bbc.co.uk is 212.58.251.195. This change is required and not directly with URLs, so the IP address is then routed to the server that con and display the home page (1).

9.12 (a) Firewall is a combination of hardware and software (1) that is designed to ch messages and requests for service from the system (1).
(b) Packet filtering is where the firewall analyses data packets that are attempti blocked unless it conforms to a set of rules; typically, the filters are set up to view the source of the data (1).
(c) Stateful inspection, often termed dynamic packet filtering, is a more secure f filtering (1). Each data packet is examined, and the state of active connection used is recorded (1).
(d) A proxy server processes the information received from the Internet and the network (1). Therefore, the website host is not in direct contact with the priv transmitted via the proxy server (1).
(e) Symmetric encryption is where the data sent is encrypted using a key (1) and the receiver to decrypt the data (1).

9.13 Viruses are small programs designed to spread between computers and to cause d operation (1). Worms are malware self-replicating programs that are designed to system resources (1). Trojans are malicious computer programs which appear to b download and install them (1).

9.14 (a) Application layer: the data that is being sent is encoded (1) into a format that i
(b) Transport layer: the data is split into parts suitable to be fitted into a data pa a number to indicate the port it will be delivered to (1) and also assigned a n the data packets can be correctly reordered once they have been received (1)
(c) Network layer: the network layer attaches the IP address of the sender of th host that will receive the data (1).
(d) Link layer: the MAC address for the hardware device sending the data is add the device receiving the data (1).

9.15 (a) File transfer protocol (FTP) is a TCP network protocol used for file transfer be
(b) Hypertext transfer protocol (HTTP) is a protocol to outline how files such as transmitted on the World Wide Web (1).
(c) Hypertext transfer protocol secure (HTTPS) has similar functionality to the H transmitted is encrypted (1).
(d) Post office protocol v3 (POP3) is a protocol used to receive email data via Po messages into text for display in a user email application (1).
(e) Simple mail transfer protocol (SMTP) is a protocol used to send email data v provided where a connection cannot be achieved between the sender and re
(f) Secure shell (SSH) is a protocol used to gain access to remote computers; it i administrators to control web servers remotely (1).

9.16 Web browser is a software application that is used to navigate and view Internet s can be selected to display using the following alternative methods: by typing a do browser, (1) by choosing a website from the result of a search (1) or by selecting th bookmarks (1).

9.17 (a) Network ID identifies the network address on which a device or computer ca
(b) Host ID identifies the address of a specific device on the network (1).
(c) Subnet mask is a number used to divide the IP address into a network addre

9.18 A public IP address is where a device is assigned to permit direct access routed via are totally unique and routable (1), whereas a private IP address is where a device for example, a home network system (1).

9.19 Network address translation is the technique used to assign a private network a r
can then be mapped to the private IP addresses of the devices in the network (1).
are that the private IP address is hidden from the Internet (1), ensuring it is more s
and the number of public IP addresses that need to be registered by an organisati
administration (1).

9.20 The websocket protocol outlines the rules for creating a persistent connection be
to enable real-time data transfer (1). The websocket protocol creates a persistent
web server after a successful handshake routine (1). This connection is full duplex,
exchanged in both directions (1).

9.21 Representational state transfer (REST) is a methodology for implementing web-base
transfer protocol (HTTP) commands to perform the CRUD function necessary to crea

REST performs the following stages when communicating with a web-based datab

- The client uses a web browser to send a request to the database (1).
- The database service request query is identified using its **URL** (uniform resou
- The **API** (application program interface) is used to link the client to the datab
- The service request and associated data are transmitted using **HTTP** (hyperte
- The database server response is in the form **XML** (extensible markup langua
  notation) (1).

9.22 Human readability – JSON is easier to read as it is written as a list of objects and t
more cluttered as it is contained within markup tags (1).

Parsing – JSON is faster to parse as it is clearly defined as a list objects and their va
and its value have to be removed from their tags (1).

9.23 Thin-client computers are low-specification devices (1); they have little processing
powerful server to provide resources, such as processing power and storage for m

Three advantages of using a thin-client model are: improved security as client acc
access to vulnerable files on the server (1); network administrator can back up all
clients' activities (1), and software and hardware can be configured and updated f

9.24 Thick-client computers are fully functional computers, so they can operate withou
and a server (1). In a thick-client network the server can give the client additional
storage and access to software that is installed on the server and run from the cli

Three advantages of using a thick-client model are: improved performance for thi
applications are processed locally on the client device (1); thick-client computers c
network where necessary, minimising the impact of server failure or the network
client software offers additional features and customisation which improve the us

Topic 10 – Fundamentals of databases

10.1 A primary key is a unique identifier (1) such as a code number that can be used to
table (1), whereas a foreign key is a field in a table which can be linked to a primar

10.2 A flat file database is a single table (1) in which each row of the table is known as a
as a field (1), whereas a relational database comprises more than one table (1) wh
are joined by linking a primary key in one table to a foreign key in another table (1

10.3 The advantage of using a relational database is that data redundancy is reduced a
duplication of data (1). This makes it simpler to keep information up to date and i
consistency of data (1).

10.4 (a) Normalisation is the formal process involved in the design of an efficient dat
process where tables are created to cause a reduction in data dependency a
(b) First normal form is where tables contain no repeating attributes or groups o
is where tables contain no partial key dependencies (1) and third normal for
dependencies (1).

10.5 (a) The SQL to create the Publisher table is:

```
CREATE TABLE Publisher
(PublisherCode INT NOT NULL, Name VARCHAR(25), Website VARCHAR
PRIMARY KEY (PublisherCode))
```

(b) The results you would obtain from running the following SQL query are:

Books.Name	Books.UnitCost	Publisher.Name
GCSE ICT	17.95	Whitchurch
GCSE Physics	16.75	Whitchurch
GCSE Music	15.75	Thornes

(c) SQL statement to add data into the Books table:

```
INSERT INTO 'Books4U'.'Books'('BookCode','Name', 'UnitCost','PublisherCod
VALUES('177TRV',' GCSE Chemistry','19.99','137','35')
```

10.6 The DBMS – provides for a centralised automatic backup of the system (1), can ass with associated access rights (1), can provide logon and password facilities for use DBMS programs and development of associated software tools (1).

10.7 In a DBMS the data is separated from the applications that access it, so programs main advantage of this is that database administrators can modify the software to the data will remain unchanged by these programs (1).

10.8 A record is locked when it is being accessed by a user with write access (1); this pr and saving the record until the original user has completed their database transac ordering concurrent transactions are based on the timestamp and the precedence (1), so a higher precedence command can be executed before older timestamp tra

Topic 11 – Big data

1. Big data is based on the following characteristics:
   - Volume – organisations gather and store large amounts of data; the amount whether or not it is big data (1).
   - Velocity – data streams are collected in a near-to-real-time fashion, making t challenge (1).
   - Variety – data comes in a wide range of formats, such as: text, audio, video, data (1).

2. Big data can be structured or unstructured as outlined below:
   - **Structured data** –data defined as appropriate for a relational database in a r consequently, this data can be analysed and queries can be used to extract u
   - **Unstructured data** – can be defined as data that is difficult to organise and is database in row and column format (1). Machine learning data analysis techn to detect patterns in this data and extract useful information in a cost-effect on unstructured data due to the range of formats used (1).

3. Definitions:
   a) Functional programming is a paradigm based on the use of functions to dete use expressions similar to mathematical expressions to calculate the value o
   b) In functional programming, data structures are immutable, meaning that the value of input data at the time the function is executed (1). Therefore, new d than changing the original data structure, so a function to update the value o with updated value from the old array (1).
   c) Statelessness means each function is calculated with no reliance on any data function inputs (1); there is no dependence upon events that happened previ
   d) Higher-order functions are functions that either take other functions as an in function as an output (1).

Topic 12 – Fundamentals of functional programming

1. The functional paradigm uses programming languages that evaluate mathematica imperative method where values are assigned to variables (1); to summarise, varia functions (1). Functional programs are used to solve problems in complex structu and it is, therefore, easier to determine errors.

2. A function can be defined as a relation between input values from the domain (1) codomain, in which each input is related to exactly one output (1).

3. $f(x) = 2x^2 + 5$
   $= 2(3*3) + 5 = 23$ (1)

4. A first-class object is a language object which supports the operations normally av appearing in expressions (1), being assigned to a variable (1), being used as an argu returned as an output from a function call (1).

5. Composition of functions is the process of combining two functions by applying th (1). A technique widely used in functional programming where complex functions functions (1).

6. Composite function $(g \circ f) = (14 + x)^3$ where $f(x) = (14 + x)$ and $g(y) = y^3$ (1)

7. Definitions
   a) The **map function** applies a given function to each of the elements in a list to same order (1).
   b) **Filter function** is a higher-order function that processes a list or data structu elements that match the specified criteria (1).
   c) **Reduce or fold function** is a method that can be used to reduce a list to a sin recursive function (1).

8. Trace of the fold or reduction function to find the product of the list [1, 2, 3, 4, 5]:
   1 mark for each correct line

List	Result	Explanation
[1,2,3,4,5]		Original list
[2,3,4,5]	1	Fold left, by removing the left-hand element fro
[3,4,5]	1 * 2 = 2	Remove next element (2) from list and multiply b
[4,5]	2 * 3 = 6	Remove next element (3) from list and multiply b
[5]	6 * 4 = 24	Remove next element (4) from list and multiply b
[]	24 * 5 = 120	Remove last element (5) from list and multiply by
Function completed – all elements of list [1,2,3,4,5] have been multiplied		

9. The head = 9 (1), the tail = [11, 17, 18, 27, 28, 29] (1) and the length = 7 (1).

10. Result of prepending [7] to the list is [7, 9, 11, 17, 18, 27, 28, 29] (1).