Zig Zag Education

Computer Science GCSE (9–1) | AQA | 8525

Course Companion

for AQA GCSE (9–1) Computer Science

zigzageducation.co.uk

POD 10590

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Teacher's Introduction

Welcome to the AQA GCSE Computer Science Course Companion, which has been produced for specification code 8525, for first teaching September 2020 (assessment from 2022 onwards).

I hope you find it useful in framing your teaching of this new course. As an experienced Computer Science teacher, author, consultant and examiner, I have attempted to draw upon all my knowledge and experience to create in order to create an effective resource, which I hope will prove equally valuable for teachers and students alike.

You will note from the new specification that a wealth of new topics have been added into the course. This embraces the ever-changing nature of the development and use of technology. I have tried to cover the detail that is required for these new topics, but it can be difficult to predict every aspect that may be drawn upon. This resource is designed to be a foundation to the course, to promote the necessary learning. You may want to explore some topics further after reading the content given here. Throughout each chapter, you will find marked the specification points that are covered in each section.

In the resource, you will find descriptive text for the specification points, a range of real-life examples, keywords and definitions, and discussion points to promote discussion of key aspects in the classroom. You will also find some practice questions at the end of each chapter; suggested answers are provided at the back of the resource.

I hope you find the resource helpful and that it aids you greatly in the teaching of GCSE Computer Science.

Happy teaching!

Remember!
Always check the exam board website for new information, including changes to the specification and sample assessment material.

Chapter 1: Algorithms

In this chapter you will learn:

- How to approach problem solving using algorithms and computational
- How to measure the effectiveness of an algorithm
- Standard algorithms for searching and sorting d

Problem solving is a skill used in more areas than just computer science. Ev
follow **algorithms** to complete tasks without even realising, where to complet
must follow a set of smaller steps. The most basic example would be pou
of water. Firstly we must get the glass out of the cupboard. Then we must
the tap. Then we must turn the tap on. Then we must fill the glass with wat
must turn the tap off. And then we can drink it! But even then, we can brea
we turn the tap on? How much water do we put in the glass? When we writ
need to break down the steps as far as possible. This is called *computationa*

Note: A common misconception amongst students is that an algorithm is a
algorithms are used *in* computer programs, you should know that an algorit
steps to solve a problem – not the completed program used to solve it. The
same result everytime they are followed.

What is computational thinking?

AQA Specification Reference

☑ Understand and explain the terms: algorithm, decomposition, abstraction.

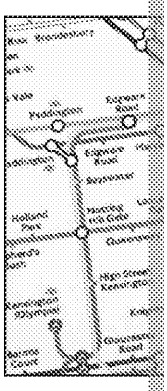
Computational thinking is not learning to think like a computer, but learnin
how to interpret problems and break them down in a logical way in order to
find a solution. To do this we can use **abstraction** and **decomposition**.

- *Abstraction* involves taking away detail that is not important so that
- *Decomposition* involves breaking down a problem into smaller prob
  individually, to build a solution.

Example – the London Underground

An example of abstraction that you might not have thought about is the London Underground. The map does not show you the stations' true distance between each other, or the shape of the track. The layout was specifically designed in a way that allows the reader's mind to concentrate on working out which track will take you where from each station. Any other information is not helpful.

So in this case, the problem is how do you get from station A to station B, and the necessary information is each station, and how they are connected. The information that is not needed is the price of a ticket, the curvature of the tracks, the model of tube train and so on!



Metro maps are a
know which stati
actual relative po

What considerations should be made when writ

AQA Specification Reference

☑ Explain simple algorithms in terms of their inputs, processing, outputs and

When writing algorithms, it is important to consider the following items:

Inputs

The data that we give to an algorithm is called an 'input'. This can come in keyboard, external files, mouse clicks and so on. In each case the input ma that should be considered when writing computer programs – for instance, number or store it as a character instead of a number, which could cause computation.

Outputs

The values that a program returns are known as 'outputs'. These might be screen, or values written to an external file.

Processes

A process is an action that is performed in the stages of your algorithm. In may be to work out the neighbouring stations of a particular stop.

Purpose

Finally, the purpose of the algorithm needs to be considered and always sh when writing algorithms. If you do not consider the purpose of the algorith something that doesn't actually perform in the way that it needs to!

Example – the water measurement probl

Consider the following problem:

You have two measuring jugs on the table in front of you, on of water, and the other one is pink and holds three litres of w

The five-litre jug is on the left, and the three-litre jug is on th

The aim is to measure four litres of water.

There are many parts of this problem that can be removed using abstractio the colour of the jugs are irrelevant. Secondly this is a problem that we can even need to use the jugs (until it comes to measuring 4 litres of water!).

Now the inputs, processes and outputs are as follows:

Inputs	Outputs
• Three-litre jug • Five-litre jug	• Ju h ur itres of water

How would you solve this problem? Try to solve it before you read the solution

Solution:

1) Firstly, the three-litre jug needs to be completely filled.
2) The three-litre jug should be poured into the five-litre jug.
3) The three-litre jug needs to be completely filled.
4) The three-litre jug should then be used to fill the five-litre jug to th
5) The five-litre jug now needs to be poured away.
6) The remaining contents of the three-litre jug should now be poured
7) The three-litre jug needs to be completely filled.
8) Finally, the three-litre jug needs to be poured into the five-litre jug

Discuss: prove that these steps work correctly.

We have described the solution in a series of steps in written English. The f
other methods of effectively describing an algorithm – psuedocode and flo

How can we represent algorithms visually?

AQA Specification Reference

☑ Use a systematic approach to problem-solving and algorithms using pseud

In the pouring a drink example given at the start of this chapter a basic algorithm was described in sentances. While this is useful for humans to justify each step, there are much clearer ways to describe the steps of an algorithm.

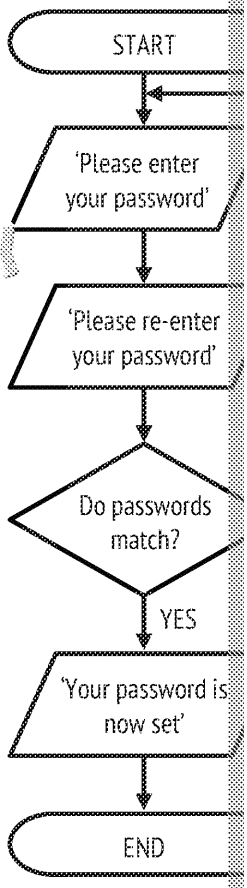
Flow charts

A flow chart is a diagram that we can create to plan and demonstrate the flow of data in a solution. When creating flow charts we use a series of symbols to represent the different elements of the program; these are:

Symbol	Explanation
	*Start/stop* – used to show where the beginni
	*Input/output* – used to demonstrate where o or provide us with an output.
	*Process* – used to show any processes or calc our flow chart.
	*Decision* – used to demonstrate a decision o our flow chart. It will have a 'yes' and a 'no'
	*Subprocess* – used to show where a subproce
	*Arrow* – used to show the flow of data throu

Let's take a simple password verification program. This is a program that will ask a user to set a password and re-enter it to verify they originally entered the password they were meant to. We want our solution to allow our user to do the following:

- Input their choice of password
- Re-enter their password
- Make sure the first password entered is the same as the second password entered
- Output a message to say whether the password has been successfully set or not
- Keep asking the user to set their password until they are successful



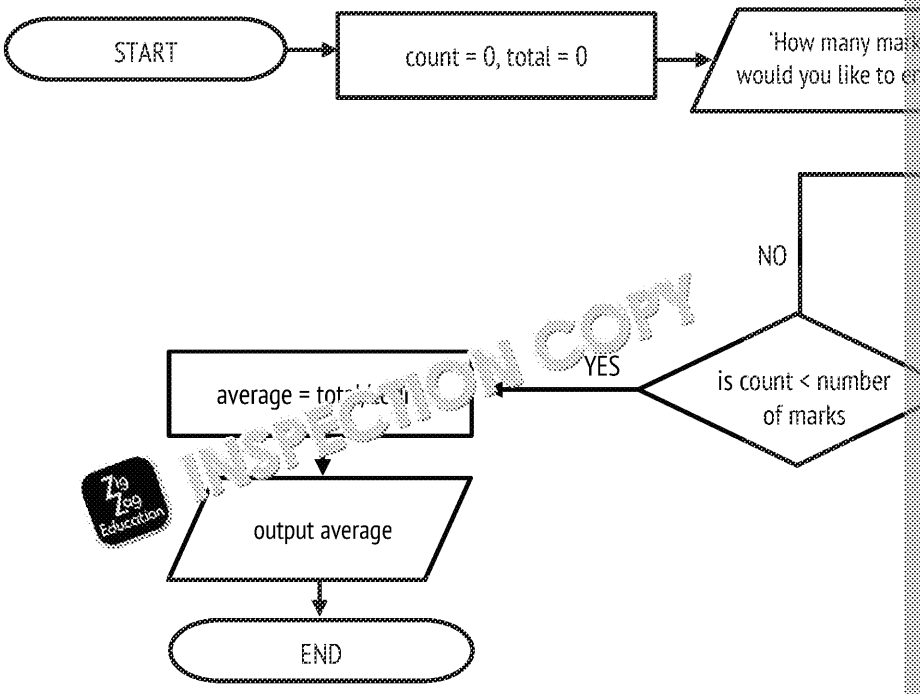
We have decomposed our problem into the inputs, outputs and processes, and the flow chart to the right can be made from these steps.

Let's create another flow chart for another problem.

To create a program that will calculate the average mark for an exam, we'll need it to do the following:

- Allow the user to input the number of marks they want to enter
- Keep a count of the marks entered
- Keep a total of the marks entered
- Allow the correct number of marks to be entered
- Calculate the average mark
- Output the average mark

We have decomposed our problem. We can now create a flow chart to repr



Pseudocode

Alternatively, we can represent the design of an algorithm using **pseudocod**
Pseudocode is a way of writing a program in programming-type statements
that are not specific to any programming language. There is no set standar
for pseudocode, but AQA have provided a guide to their standard for
pseudocode on their website, so this is the standard we will use.

When writing programs in pseudocode we can use the following statements

Statement	D
variable ← 1	This allows us to declare a
variable ← USERINPUT	This allows the user to in
OUTPUT variable	This allows us to provide printed to the screen.
FOR i ← 0 TO 3 print(variable) ENDFOR	This allows us to create a perform a set of instructio
WHILE variable = false variable ← input("user prompt") ENDWHILE	This allows us to create a condition is checked at th
REPEAT variable ← USERINPUT UNTIL variable = true	This allows us to create a condition is checked at th

IF variable = 1 THEN
  OUTPUT 1
ELSEIF variable = 2 th
  OUTPUT 2
ELSE
  OUT
ENDIF
	This allows us to create s
	We can add multiple sele elseif.

CASE variable OF
  1: OUTPUT 1
  2: OUTPUT 2
  ELSE
  OUTPUT 0
ENDCASE
	This allows us to create s a set number of options.
	We can add a default opti do not match an option.

FUNCTION double(parameter) RETURN parameter * 2 ENDFUNCTION calling: variable ← double(argument)	This allows us to store a s We can then call the func

PROCEDURE name(para er
  instruction
  ins io
END P URE
 	
calling:
 	
name(argument)
	This allows us to store a s procedure.
	We can then call the proc out the set of instructions
	These differ from functio

Statement	D

`name ← [1,2,3,4,5]`
 	
`name ← [[1,2],[3,4]]`
 	
`name[0] ← "entry1"`
`name[1] ← "entry2"`
`name[0, 0] ← "entry1"`
`name[0, 1] ← "entry2"`
 	
`print(name[1`
`print(name[0, 1])`
	This allows us to create a dimensional array, the se
	
	We can then assign, amen element in the array.

`READLINE("myfile.txt", 2)`
 	
`WRITELINE("myfile2.txt",3,data)`
	These are the statements They allow us to read and
	
	The first example reads t "myfile.txt".
	
	The second line writes da "myfile2.txt".

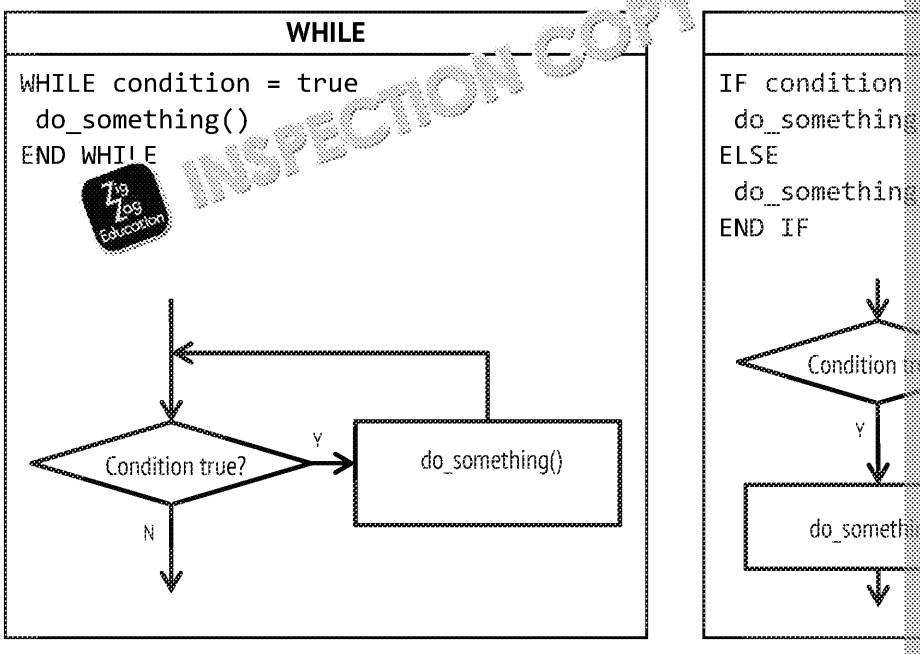
We can use this pseudocode standard to write a program to represent our f program:

```
match ← false
WHILE match = false
    password1 ← USERINPUT
    password2 ← USERINPUT
    IF password1 = password2
        OUTPUT "Your password has been set"
        match ← true
    ELSE
        OUTPUT "Your passwords do not match"
        match ← false
    ENDIF
ENDWHILE
```

Discussion point: Why might you wish to use pseudocode over flow charts

Which method is better for describing an algori

The flow chart made from an algorithm can be seen as equivalent to pseud
of steps to solve a problem, just in a different way. In fact, you can easily t
equivalent flowcharts for IF statements and WHILE statements have been s



Overall, there is no real 'better method', programmers tend to use both whe
charts give you a good idea of how data mov[illegible] the program, pseudo
can be used to translate directly int[illegible] language of your choi

How can we [illegible]ate the efficiency of an algori

AQA Specification Reference

- ☑ Understand that more than one algorithm can be used to solve the same p
- ☑ Compare the efficiency of algorithms that solve the same problem.

There is no right way to write an algorithm that solves a problem; however
are often ways that are better than others. When we talk about the efficien
algorithm we can measure it in two different ways: the amount of time it ta
run, and the amount of space that it uses on a computer. Of course, there i
other measure: how readable the code is – however, this is more to do with
create maintainable code, and doesn't affect the overall run time of the pro

The time a program takes to run is measured against its input. If the progra
inputs, and needs to perform some calculation for each input, then we say t
program has linear run time. If multiple calculations need to be made betw
run time becomes slower and we say that the program has a polynomial ru
computing becomes impossible as the number of inputs increases – s
solve the problem are exponential in run time. It might take two
for two inputs, eight seconds for three inputs, and if this pattern continues
billion seconds!

One example (that will be covered later) is searching. Linear searches can
100,000 elements in a list, then in the worst case 100,000 comparisons nee
would only need 17 comparisons to search a list of 100,000 items in the wo

Consider the following programs that find the sum of the first *n* integers gr

Program 1	
n ← USERINPUT sum ← 0 FOR count ← 1 TO n sum ← sum + count END FOR OUTPUT sum	n ← USERINPUT OUTPUT n*(n+1)/

The first program adds a number sequentially to the sum variable. This up to the number 100,000, the program needs to perform 100,000 calculati well-known formula for the sum of the first n integers, and regardless of th perform three operations (multiply, add, divide)! In this case program 2 is *m*

Did you know?!

This is an entire field of computer science known as 'complexity theory'. If you choos A Level, you will be given a basic introduction to this field, which involves properly me complexities of an algorithm!

How can we determine the purpose of an algori

AQA Specification Reference

☑ Determine the purpose of simple algorithms.

In your exam you may be given some pseudocode, and be asked to explain improved. In the following example, can you deduce the purpose of the alg

```
x ← INT( USERINPUT )
y ← INT( USERINPUT )

x ← x + y
y ← x - y
x ← x - y

OUTPUT x, y
```

Without meaningful names or comments, this pseudocode does not give an as to what is happening. This is where we can use **trace tables** to help us o Trace tables allow us to follow the algorithm after each step that is perform These tables have a column for each variable, and a column for any output algorithm may produce. Suppose the input is x = 2 and y = 6. Then:

x	y
2	6
8	
	2
6	

After writing the trace table for this algorithm we can see that on the input (x = 6, y = 2).

Discussion point: Create a trace table for the inputs x = 5, y =

What is the purpose of searching and sorting al

There are two categories of algorithm that you need to know: these are **sea** **sorting** algorithms. Both are used on data sets to make them simpler to un

Searching algorithm – the step-by-step procedure used to find an item of data in a data set

A *searching algorithm* is one that is designed to f When a data set is very large, running into hundr manually trying to fi[illegible] particular item of data algorithm will perform this function for us. There al[illegible] that you need to know: these are **linea**

A *sorting algorith*[illegible] that is designed to sort a set of data into order (eith increas[illegible]decreasing; we will always use increasing in the examples). Th are vari[illegible]ways in which we can sort a data set into order; the two methods need to know are **bubble sorts**, and **merge sorts**.

How do we perform a linear search?

AQA Specification Reference

☑ Understand and explain how the linear search algorithm works.

A linear search is a simple sequential search of a data set. The algorithm will start at the beginning of the data set and moves through each data iter one by one. It will do this until it finds the data item it has been set to look for, or it reaches the end of the data set without finding a matching data item. A linear search is suitable for searching an [illegible] any data type, unlike binary searches (next section) that only work on orderable items.

If we had a data set of numb[illegible] wanted to find a particular number search. For example, we have the following data set of numbers.

10	[illegible]	31	15	85	69	75

We want to search the data set to see whether the number 85 appears in it. first number in the data set.

Is 85 = 10?

10	25	31	15	85	69	75

85 is not equal to 10, so the algorithm will move on to the next item.

Is 85 = 25?

10	25	31	15	85	69	75

85 is not equal to 25, so the algorithm will move on to the next item.

Is 85 = 31?

10	25	31	15	[illegible]	69	75

85 is not equal to 31, so the [illegible] will move on to the next item.

Is 85 = 15?

10	[illegible]	31	15	85	69	75

85 is not equal to 15, so the algorithm will move on to the next item.

Is 85 = 85?

10	25	31	15	85	69	75

Yes, it is! The algorithm will stop here as the data item 85 is found.

We can write an algorithm in pseudocode to represent how a linear search

```
position ← 0
list ← [10, 25, 31, 15, 85, 69, 75, 21, 19, 6]
length ← list.length
number ← USERINPUT
WHILE position < length AND list[position] ≠ numb
    position ← position + 1
ENDWHILE
IF position = length then
    print("The number is not in the list")
ELSE
    print("We have found your number!")
ENDIF
```

How do we perform a binary search?

AQA Specification Reference

☑ Understand and explain how the binary search algorithm works.

A binary search is another type of searching algorithm. We mostly use a bin have a list of data that is in order. A binary searching algorithm works by d the item in the middle. If when the list is split there is an even number of i first item on the right-hand side.

If we order the list of number we used previously, we can use a binary searc

We had the following set of numbers:

10	25	31	15	85	69	75

If we order them, we will have:

6	10	15	19	21	25	31

We can search the data again to see whether the number 75 appears in it. We

6	10	15	19	21	25	31

We have an even number of items, so we look at the data in the last position a whether 75 is equal to this number first. 75 is not equal to 21, so we have not is greater than 21. It is, so we can discard the list on the left-hand side and or

25	31	69	75	85

We then divide this list in half:

25	31	69	75	85

This time we do have an odd number and therefore have a central number. we have found 75 yet not equal to 69, so we have not found it. We then 69. It is greater than 69 so we can discard the list to the left-hand side and the central poi for the next step.

75	85

We then divide this list in half:

75		85

We have an even number of items, so we look at the data in the last positio
see whether 75 is equal to this number first. It is! So we have found 75 in

We can write an algorithm in pseudocode to represent a binary search for t

```
list ← [6, 10, 15, 19, 21, 25, 31, 69, 75, 85]
length ← list.length
number ← input("Wha[illegible]er would you like to fin
lowerBound ← 0
upperBound ← length - 1
match ← false
WHILE match = false AND lowerBound ≠ upperBound
    midPoint ← round((lowerBound + upperBound)/2)
    IF list[midPoint] == number THEN
        print("We have found your number!")
        match = true
    ELSEIF list[midPoint] < number THEN
        lowerBound ← midPoint + 1
    ELSE
        upperBound ← midPoint - 1
    ENDIF
ENDWHILE
```

Which searching method is best?

AQA Specification Reference

☑ Compare algorithms that use linear and binary search algorithms.

When the list is sorted, it makes much more sense to use a binary search in search on an array of length n will take n comparisons. A binary search on to the nearest integer) comparisons. The table below shows the maximum looked at before an element is found – clearly, you can see that for large a

Elements	100	100,000	500,000	1,000,0
Linear search	100	100,000	500,000	1,000,0
Binary search	7	17	19	20

When the list is unsorted, clearly binary search cannot be performed – altho performing, a binary search is slower than just performing a linear search, i if there are multiple searches it makes sense to sort once, and then perfo searches.

Did you know?

The s[illegible]oblem that we have tackled looks for the existence of an element, and There a[illegible]other search problems that are slightly more tricky, with one being searchi element in an array. One of the hardest search problems is efficiently searching a b are allowed a wild card symbol.

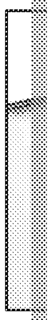
How do we perform a bubble sort?

AQA Specification Reference

☑ Understand and explain how the bubble sort algorithm works.

A bubble sort is the simplest sorting algorithm to understand. A bubble sor first of all checks the first item against the second item.

If the first item is greater than the second item, the algorithm knows they are not in order, so it swaps them. If the first item is less than the second item it just leaves them as they are.



Thi 'bu

It then moves onto the second item and checks this against the third item in the list. If it is greater than the third item, it swaps them, otherwise it leaves them as they are, and so on. It will go all the way through the data set and then start again at the beginning to do the same thing again. This is called *passing through* the data. It will repeatedly pass through the data until it makes no changes to the data; it then knows they are in order.

We can use part of our original data set:

10	25	31	15	85

We first of all look to see whether 10 is greater than 25. It is not, so they st

10	25	31	15	85

We then look to see whether 25 is greater than 31. It is not, so they stay as

10	25	31	15	85

We then look to see whether 31 is greater than 15. It is, so we swap them.

10	25	15	31	85

We then look to see whether 31 is greater than 85. It is not, so they stay as

10	25	15	31	85

We then look to see whether 85 is greater than 69. It is, so we swap them.

10	25	15	31	69

This completes our first pass through the data. We can now begin a second

10	25	15	31	69
10	15	25	31	69
10	15	25	31	69
10	15	25	31	69
10	15	25	31	69

In that pass the numbers 15 and 25 were swapped. Even though we can se algorithm does not yet know this. It needs to confirm that no swaps are ma

We can write an algorithm in pseudocode to represent a bubble sort:

```
list = [10, 25, 15, 31, 69, 85]
length = list.length - 1
swapped = true
WHILE swapped = true
 swapCount = 0
 for n = 0 to length - 2
    if list[n] > list[n+1] then
       swap(list[n], list[n+1])
       swapCount = swapCount + 1
    endif
 next n
 IF swapCount = 0
    swapped = false
 ENDIF
ENDWHILE
```

How do we perform a merge sort?

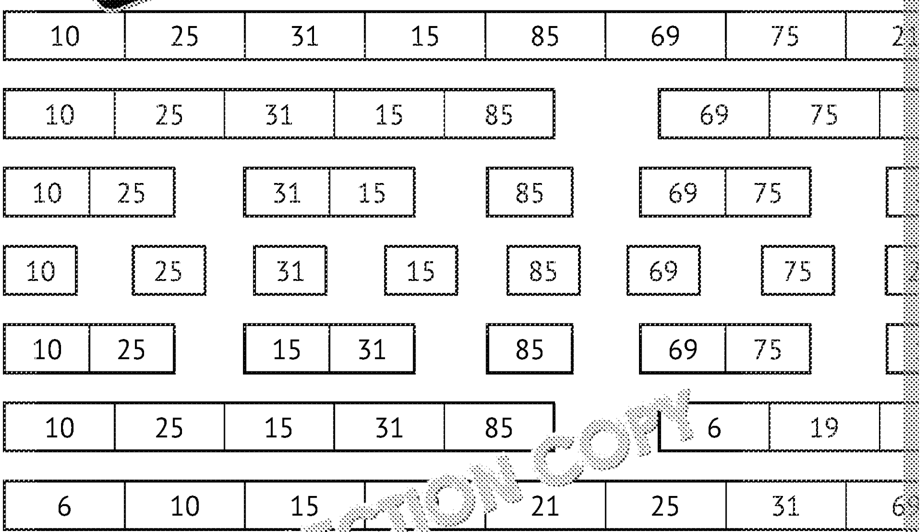
AQA Specification Reference

☑ Understand and explain how the merge sort algorithm works.

A merge sort is an example of a Computer Science technique called 'divide a… known sorting algorithms as it makes the lists smaller, so they become easie…

A merge sort works by dividing a list in half repeatedly, till it has a set of lis… then merges together each list till it has ordered the whole list again.

We can … our original list.



Which sort is better?

AQA Specification Reference
☑ Compare and contrast merge sort and bubble sort algorithms.

Bubble sorts are one of the worst methods known to sort data. However – t when sorting data, as elements are just swapped /as a result we say that th are one of the faster methods of sorting but needs extra storage in the inter may not actually be possible!

When extra space is allowed, merge sorts are much more preferable. Althou expect ti of each algorithm, you should know that merge sort is fa the wo run time increases for each sort depending on the number o putting an item into place takes one unit of time).

Elements	2	4	8	256
Bubble sort run time	4	16	64	65,536
Merge sort run time	2	8	24	2048

Did you know?!

There are multiple more ways of sorting an array of elements. The merge sort is methods of sorting data, and bubble sort is one of the worst! The worst sort is c purposefully to be the worst possible sorting algorithm. The sort randomly shuffl and if it isn't then it starts again! The probability of correctly sorting a deck this w Which is equal to 0.000000000000 000000000000000000000000000

Disc : Can you think of any other ways to sort data? For exam sorti ck of cards. Is the way you sort this different from the sorts de

Note: For the exam, you need to be able to recognise the logic of a search be given the algorithm and have to describe what it does. You may be giv show how you are using it to find an item of data. You may be given the a incomplete, and you have to correct the algorithm or complete it. Therefo are very familiar with the look and logic of all four of these searching and part of Computer Science!

Chapter Summary

- Computational thinking is learning to break down problems in a logica
  This involves both abstraction and decomposition.
- An algorithm is a sequence of steps or instructions that are carried out
  task. We can use two methods to plan an algorithm: flow charts and p
- There are multiple ways to write an algorithm, some being more efficie
  algorithms the memory needs to be considered as this might affect ho
- A binary search algorithm is one that is designed to look through a data se
  Th two types of searching algorithm that you need to know: the
  search.
- A linear search is a simple sequential search of a data set. A binary sea
  repeatedly dividing a list in half until it finds the item of data.
- A sorting algorithm is one that is designed to sort a set of data into orc
  know are bubble sort and merge sorts.
- A bubble sort starts at the beginning of a list and compares each item
  if this is the case.
- A merge sort works by dividing a list in half repeatedly, till it has a set
  It then merges together each list till it has ordered the whole list again

Exam-style Questions

1. State what is meant by the term 'computational thinking'.
2. Explain what is meant by the term 'abstraction'.
3. Consider the following set of numbers:

   3, 24, 1, 15, 65, 87, 2, 19

   Show that a binary search can be used to find the number 65.
4. Explain two circumstances in which a linear search might be quicker th
5. Consider the following set of numbers:

   5, 23, 1, 12, 78, 3, 11, 2

   Perform a merge sort on the numbers.
6. State when a bubble sort is more appropriate to use than a merge sort.
7. Using an array of integers, write an algorithm that swaps the first elem

Chapter 2: Programming

In this chapter you will learn:

- Various concepts fundamental to programming
- Useful tools needed to write effective programs
- Operations that can be performed in program code
- How programs can interact with files already on the computer

Why do we need programming?

AQA Specification Reference

- ☑ Understand the concept of a data type
- ☑ Understand and use the following appropriately: integer, real, Boolean, cha

Programming allows us to perform computations much faster, and more accurately than humans. If you were given some data and asked to analyse the browsing habits of 1,000,000 customers for an online shop it would be impossible.

So instead, we use computers. Even though computers see everything as a series of 1s and 0s we can actually represent a whole range of data types that will be briefly described below:

Data type	Description
Integer	These are whole numbers only
Real	These are numbers that can have a decimal part as well
Boolean	This has two values only: true and false
Character	This is a single letter, number or symbol
String	This is used for text, and can include any character

Note: Different programming languages refer to these data types in differe programming language VB.NET, real numbers are called doubles – in othe

What are the fundamental concepts of program

AQA Specification Reference

- ☑ Understand how the following statement types can be combined in pro assignment, iteration, selection, subroutines.

There are three basic constructs that are the foundations of every program imperative programming languages; these are **sequence**, **selection** and **itera**

Construct	Description
Sequence	The order in which the instructions need to occur in an algorit instructions are not carried out in the correct sequence, a prog output. Therefore, we need to carefully consider the order in when we are designing an algorithm.

Construct	Description
Selection	When writing a program, it may be necessary to create a way f paths. This is dependent on **conditions**. Conditions allow us t This method for creating different paths in a program is called
Iteration	Sometimes when we write a program we will need to repeat in instructions is called iteration. We can put the instructions we block of code called a loop. Everything in this loop will get re times, or until a condition is met.

Three other important concepts are variables, constants and assignment.

When we create a program, we will need to create a way for our user to input data into a program. We will also need to create a way to store the input from our user, and a way to output any data we require to our user. We can do this by using **variables** and **constants**.

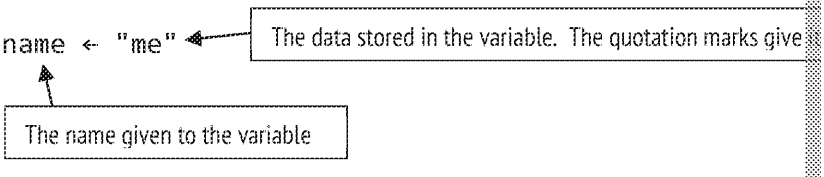
To store the data that is input into our program we will need to create a data store. By naming the variable or constant, a link is made to the memory location where the data is stored. When we want to put data into the store we must **assign** it to a variable (or constant).

> ***Did you know?!***
>
> *When programs were first written, memory locations had to be referred to by th being a huge 16 bits long). These days we just use variable*

Variables

A variable is a data location that is given a name. It stores data that can be cha program. The name of the variable links it to the memory location where th data in a variable is by **assigning** it. The arrow symbol is used to assign data

For example:



We can reassign the data that is stored in our variable at any point that is re For example:

```
name ← "Bob"
name ← "Jane"
```

In this instance name will store 'Bob' until it is reassigned to store 'Jane'.

We can give any name the variable to our data store, but we should choose be meaningful and relate to the data that is stored. We should also avoid p names as this can sometimes cause problems in our program.

> **Note**: The ability to choose meaningful identifier names for your variables assessed in programming questions in the Paper 1 examination.

There will be more on global and local variables later in this chapter.

Constants

Constants store data that will not be changed throughout the execution of t
we need to use repeatedly in a program, we *could* hardcode the value into t

An example of hardcoding could be that a score needs to be changed by 20
button – in every place in your program code that changes the score you co
what would happen if the requirements changed and the score needed to be
that you have written 1.2 would need to be replaced by 1.1 – and you would
all of the right values! If you had used a constant you would only have need

Hardcoding the values can cause two main problems, though:

1. It is bad programming practice to hardcode values into a program.
2. If we want to change the value, we will need to find all instances o
change it.

If we use a constant to store the value, we can set it to the value we want t
Using a constant throughout your program instead of hardcoding the value
values at once.

Some meaning is also given to the constant, as if a programmer looked at y
be no description of what the purpose of that value is. Instead, if there is a
instantly know that it is referring to the current VAT rate. This is called a se

We store data in a constant in the same way that we store it in a variable, by assigning it to a constant name.

For example:

```
CONST pi ← 3.1415
```

Dis
ar
co
ap
th

What is meant by iteration?

AQA Specification Reference

- ☑ Use definite and indefinite iteration, including indefinite iteration with
end of the iterative structure.
- ☑ Use nested selection and nested iteration structures.

There are two different types of iteration – indefinite and definite. They bo
one is more appropriate than the other.

Indefinite iteration will loop over your code until a condition is met. This n
certain variable to be in a certain range, or a certain statement to be true o
characterised by WHILE loops and REPEAT UNTIL loops. This is known as b

```
WHILE condition = false
    do_something()
ENDWHILE
```

```
REPEAT
    do_s
UNTIL co
```

Definite iteration terminates after a known amount of steps. This type of it
loops. This is known as being count controlled.

```
FOR counter ← 1 TO known_amount
    do_something()
END FOR
```

We can also 'nest' iteration and selection statements. This simply means th

```
FOR counter ← 1 TO known_amount
    IF condition = false THEN
      WHILE condition = false
            do_something()
      END WHILE
    ELSE
      do_something_el
    END IF
END FOR
```

How can we write 'good' program code?

AQA Specification Reference

☑ Use meaningful identifier names and know why it is important to use them

When writing program code, you should assume that other people will read it at some point. Not only is this helpful for other people, but it is also helpful for yourself if you need to revisit code that you have written in the past. It is especially useful for when others read your code as it is essentially a form of communication.

One of the most common ways to improve readability is to use meaningful identifier names. For instance you should not label your variables 'my_var1, my_var2, my_var3' etc., but instead you should name the total_score'. This way some meaning can instantly be deduced from the na

Another method of readable, maintainable code is to use comments – this from meaningful identifier names one step further, and lets us describe wha doing separate from the code. We will add comments to describe how a ce

We add comments in our pseudocode by using two forward slashes (//) foll (***Note:*** *The symbol uses for comments varies between programming languages*)

For example: `name ← "Bob"  // This is a variable that store`

By adding comments to our code, this means that when we look at it again to use our code, we can read the comments and follow the structure of how

We can also use indentation to make our code more readable in the future. on us indenting sections as it is part of the programming language (i.e. Pyth selection; others do not insist on this but we should still do it. By indenting see what instructions are meant to be executed inside the loop or as a result

```
x ← 1
if x = 1:
    print("Hello world")
```

In Pyth... ...nts do not run correctly without an indent here.

Did you know?!

Even though most programming languages do not enforce indents, comments a should always try to use them anyway. Some code that you have written withou efficient as possible, but if you cannot read it, the code is seen as bad!

How are arithmetic, relational and Boolean ope

AQA Specification References

- ☑ Arithmetic operations: addition, subtraction, multiplication, real division, inte
- ☑ Relational operations: equal to, not equal to, less than, greater than, less than o
- ☑ Boolean operations: NOT, AND, OR.

It is essential that computer programs are ab[illegible]nipulate data that we
Arithmetic, relational and Boolean o[illegible]ns help us to do so.

Arithmetic Operati

There ar[illegible]an[illegible]*ic operators* that we need to understand in order to
with th[illegible]erators we can manipulate numbers:

Operator	Description
+	Addition
–	Subtraction
/	Division
*	Multiplication
Exponential (^)	Repeated multiplication
Remainder (MOD)	The remainder left over when a number is divided b
Integer division (DIV)	The number of times a number can be subtracted b

DIV and MOD are both operators that you would have learnt when first lear
going into fractions). One way to think about it is us[illegible]g bins.

Suppose we want to calculate 7 DIV 3 and 7 MOD 3.

- Suppose the bin h[illegible] a ca[illegible]city of 7 units, and each item we put in
- Therefo[illegible]n we 2 items into the bin, and there is 1 unit of free
- [illegible]DI[illegible] is equal to 2, and 7 MOD 3 is equal to 1.

Discussion point: Arithmetic operators are typically used on numbers. Can you think of any operations that you would perform on a string?

Relational Operations

Relational operators are useful for indefinite iteration – you can check when
a certain value using a statement that evaluates to true or false.

=	Is equal to – this can have a true or false outcome
≠	Is not equal to – this can have a true or false outcome
<	Is less than – this can have a true or false outcome
>	Is greater than – this can ha[illegible]e or false outcome
⩽	Is less than or eq[illegible] t[illegible] can have a true or false out
⩾	Is great[illegible]an o[illegible]equal to – this can have a true or false out

Boole[illegible]e[illegible]tions

Boolean operators can be used to join conditional statements together to fo

A AND B	True if both statement A AND statement B are true
A OR B	True if statement A OR statement B (or both) is true
NOT A	True if statement A is false

Example – Bus tickets

Free travel should be given to those over the age of 75, or if the traveller already has a ticket. Otherwise they should be charged £4.

```
IF age > 75 OR traveller_has_ticket = true THEN
      ticket_price ← 0.00
ELSE
      ticket_price ← 4.00
END IF
```

What operations can be performed on strings a

AQA Specification Reference

☑ String handling operations: length, position, substring, concatenation, c

Arithmetic operators work on numbers. What would happen if why tried to
The most likely thing to happen would be an error – as this operation is no

Other data types have operations unique to themselves. For example, inser
operation. In particular you should know how to manipulate strings and ch

Suppose we have the values "Bob" and "Steve" assigned to the variables na

Command	Description
LEN (length)	This gives the number of characters that are in the string. This will include any spaces.
UPPER	This changes all the characters in the string to upper case.
LOWER	This changes all the characters in the string to lower case.
POSITION	This gives the position of a particular character in the string.
SUBSTRING	This selects a particular part of a string. It starts at the place in the string set by x and selects the next number of characters set by y.
+ (concatenation)	Concatenation joins two strings together.

Note how + is used for addition in numbers, and concatenation in strings. T
when using + with different data types – what is the result of a string + nu
is converted to a string, so "ABC" + 4 would equal "ABC4", but in the pro
example, you must convert the number to a string or an error will occur. Th
operations are useful.

Command	Description
INT	Converts a string to an integer.
REAL	Converts a string to a real.
STRING	Converts a real or integer to a string.

There are even operations specific to characters (and not strings), such as ch
letter to its number representation (see Chapter 3). Let `chr1 ← 'b'`. The
followi e.

Command	Description	Exam
ASC	Conversion from character to ASCII code	ASC(chr1)
CHR	Conversion from ASCII code to character	CHR(98)

What are data structures and how do use them?

AQA Specification References

- ☑ Understand the concept of data structures
- ☑ Use arrays (or equivalent) in the design of solutions to simple problems
- ☑ Use records (or equivalent) in the design of solutions to simple problems

Data structures are also known as 'abstract data types'. The two that you ne
records. The data types described a[illegible] of this section are often refer
Data structures are often referred to as user-defined data types.

Array

An arra[illegible]ata store that is designed to store a set of data that is all of t
list of the names of the students in your class could be stored in an array. E
called an element; each element can be accessed by referring to its positio

```
ClassList ← ["Bob", "Jane", "Bill", "Annie", "Ali"]
```

If we want to reference an element of data in the list, we refer to the data l
to note is that many programming languages label the first data location in
that the data stored in element 3 of our class list array would be Annie. Wh
we declare a name for the array and how big we want the array to be. For e

```
array ClassList[5]
```

Then to write each element of data we want to store into the array we write

```
ClassList[0] ← "Bob"
ClassList[1] ← "Jane"
ClassList[2] ← "Bill"
ClassList[3] ← "Ann[illegible]
ClassLis[illegible] ← "Ali"
```

This w[illegible]e data we require to each element in the array.

Note: *Some programming languages only support fixed size arrays (we call this
data cannot be added without creating a new, larger array and copying the con
size are often called* ***dynamic arrays****.*

This type of array is a called a one-dimensional array. We also need to kno
called a two-dimensional array. If we think of a one-dimensional array like
think of a two-dimensional array as a table of data that is stored. Similarly
dimensional array requires each element to have the same data type.

For example:

```
array TestScores [3,5]
```

The reference to elements in this type of arra[illegible]s [illegible]o parts. The first is lik
and the second is like the row refere[illegible]ti[illegible]able. This is where you nee
element the wrong way aro[illegible]potentially cause errors later on down

This two-dimen[illegible]ray will store three test scores for each of the five s

TestScore	Student Number				
	0	1	2	3	4
0	30	35	32	25	22
1	29	21	29	25	28
2	27	23	32	26	19

We can find out the test score stored for a student for a particular test by re
the test number. For example:

```
TestScores [3,1]    // This would return the test score 2
TestScores [0,2]    // This would return the test score 2
```

We write data to a two-dimensional array in the same way we write it to a
referencing the element. For example:

```
TestScores [0,0] ← 3    This writes the test score 3
TestScores [3,2] ← 2    // This writes the test score 2
```

We can change the data stored in a particular element of an array by si
test fo is remarked and a new test score needs to be entered, we can
correct location in the array. For example:

```
TestScores [1,1] ← 25    // This would overwrite the pre
```

Discussion point: Can you think of an example where you would need thr

Records

One of the common ways we often store large amounts of data is in a **database**. A database is separated into tables, records and fields.

A table will store a collection of records and fields that are all related. An organisation may have a table in a database that is dedicated to storing the customers' personal details.

A field in a database stores a particular item of data. An example of a field in a table that stores custom details would be 'customer_forename'.

A reco da base stores the data from a single collection of fields in a relating specific individual customer.

customer_forename	customer_surname	age	custo
Joe	Bloggs	35	joe@
Jane	Doe	24	jane
Bill	Ding	15	bill@
Jane	Bloggs	40	jane

This is a **record**

The whole collection of data is a **table**

We mostly store data in databases so that it is stored in a structured format for future use.

We can define records in design solutions.
A record in the database above is shown here:

```
RECOR


ENDRE
```

Did you know?!

The programming language Python does not support arrays. Instead it uses list d a list and a record. You can have multiple data types, but there is no checking th the correct data type.

How is data input and output by a computer pr

AQA Specification References

- ☑ Be able to obtain user input from the keyboard
- ☑ Be able to output data and information from a program to the computer d
- ☑ Be able to use random number generation

Inputs

When we want to allow data t[illegible] into our program, we need to creat
For example:

```
← USERINPUT
```

This will allow us to create a variable called 'name'. It will then allow us to
inputs. It also provides the user with a prompt of 'Please enter the name of

Outputs

When we want to output data to our user, we need to create an output for o

```
OUTPUT "Hello user, welcome to my program!"
```

This would output the message inside the quotation marks to the user. We
are in a data store. For example:

```
name ← "Jane"
OUTPUT name
```

This would output the name 'Jane' to the user as t[illegible] 'Jane' is stored in

Sometimes we want the computer [illegible] to generate numbers randomly,
inputting the values in ou[illegible] most programming languages have this f

We ofte[illegible] a random number between a range of lower and upper bo

```
dom_number ← RANDOM_INT(0,2)
IF random_number = 0
      THEN result ← "rock"
ELSEIF random_number = 1
      THEN result ← "paper"
ELSE # only other value is 2
      Result ← "scissors"
ENDIF
```

We can also return a random element from a data structure such as array, f

```
student ← ["Ali", "Barney", "Char[illegible]e", "Daisy",
random_student ← RANDOM_CHO[illegible]dent)
```

How can we make our programs more efficient?

AQA Specification Reference

- ☑ Understand the concept of subroutines.
- ☑ Explain the advantages of using subroutines in programs.
- ☑ Describe the use of parameters to pass data within programs.
- ☑ Use subroutines that return values to the calling routine.

Examine the following program. It [illegible] three people's names and greets

```
name1 ← USERINPUT
OUTPUT "Hello " + name1 + "!"
name2 ← USERINPUT
OUTPUT "Hello " + name2 + "!"
name3 ← USERINPUT
OUTPUT "Hello " + name3 + "!"
```

This program could be improved, as code is repeated unnecessarily. *What if* message? You would then have to change each greeting, making extra care

Instead we can use **subroutines**. These are sequences of instructions that w regular occasions in our programs. We then just need to refer to the name subroutine when we want to use the particular set of instructions. Reusing neater, more understandable programs where there is less of a chance of m

For instance, we could write a subroutine:

```
PROCEDURE greet()
    name ← USERINPUT
    OUTPUT "Hello " + name + "!"
ENDPROCEDURE
```

Then the example above can be reduced to:

```
FOR count ← 1 TO 3
    greet()
ENDFOR
```

This is much neater – and then, if a change needs to be made to the greeti instead of three times.

There are two types of subroutine that we can use: **procedures** and **function** Functions return values after they have been completed – so we can assign variable to a function call, and whatever the function output, it will be store the variable. A procedure, however, *does not return any value*.

We may wish to store the names that were input by the user. In the follow asks the user for input, greets them, and then returns the entered name so

```
FUNCTION greet()
    name ← USERINPUT
    OUTPUT "Hello " + name + "!"
    RETURN name
ENDPROCEDURE

name1 ← greet()
name2 ← greet()
name3 ← greet()
```

The last property of subroutines is that data can be passed to them, as in so
subroutine may not be accessible from inside a subroutine. Suppose we kn
wanted to greet. Then we could change our program to:

```
PROCEDURE greet(name)
      OUTPUT "Hello " + name + "!"
ENDPROCEDURE

greet("Bob")
greet("Claudia")
greet("Da
```

The va name" is used as a placeholder for the value passed into the pr

Did you know?!

*Functional programming languages are programming languages in which every ob
data to change, i.e. they do not allow variables – which means that they cannot us*

*You won't need to know about functional programming as part of this course, bu
syllabus should you continue beyond GCSE.*

Why do we pass variables into subroutines?

AQA Specification Reference

- ☑ Know that subroutines may declare their own vari , called local variab
- ☑ Use local variables and explain why it is g or ice to do so

We say that a variable is eith **global**. A global variable is one that is recognised th e whole of our program. If we use the variabl e, ecognise it anywhere in the program and use the data th ored in it at any point in our program.

Any variables that are created inside of a subroutine are not recognised by the program outside it. This means that they are local variables.

Example

```
x ← 1
FUNCTION f()
      x ← 2
ENDFUNCTION
f()
OUTPUT x
```

In the example above, the pro uses a global variable, and defines variable to two. It the function and then prints the value of the v now eq 2 the x inside the function f is a local variable, so it x – So ue that is printed is 1.

It is generally good practise to treat each variable as local in your program above. Without this, checking your program code typically becomes much l location. Global variables can also cause problems when multiple people a great care must be put in place to not use the same names.

What is meant by a 'built-in' subroutine?

AQA Specification Reference

☑ Be able to use random number generation.

Some subroutines are incredibly standard, so they are included with the pro subroutines are called *built-in* subroutines or *language-defined* subroutines. already, including printing, sorting and searching.

One function that typically comes with a programming language is a *random* a minimum and maximum number, it will produce a number randomly from

```
x = RANDOM(1,10)
OUTPUT x
```

There is no defined stand in pseudocode; for your e

It might sound odd, but the values returned by a random number generator because they are generated from an initial value that we call a *seed*, and th performed to find the next value.

If the generator used the same seed twice then the numbers can easily be p specialised hardware is required, that pulls data from various sources such a

What is meant by 'structured programming'?

AQA Specification References

☑ Describe the structured approach to programming.
☑ Explain the advantages of the structured approach.

Regardless of the programming language, ultimately all programs are translated to machine code – instructions that can be understood directly by the computer. However, solving certain problems can be made easier for humans by thinking in different ways. In programming we call these different methods of thinking *programming paradigms*.

The type of programming you do is heavily influenced by the problem. Some problems just happen to be suited towards a particular programming paradigm.

It is really important that programmers adopt a structured approach. By do by other programmers, allows for easier collaborative working and gives us making us more efficient. It also allows for better testing as you can test m certain programming constructs and rules we can stick to this.

1. Modularised code – using s makes our code more readab This breaks the problem down smaller parts, making the coding more
2. Clear, well documented interfaces to design the data flow through parameters
3. Use return values – these are variables that come back out of a sub your code where the subroutine or function call happened.

How can we test our programs effectively?

AQA Specification References

- ☑ Be able to write simple data validation and authentication routines.
- ☑ Be able to understand what is meant by testing.
- ☑ Be able to select and justify suitable test data that covers normal, boundary
- ☑ Be able to understand, identify and categorise errors in programs and algo

During the creation of our algorithms and programs, and also when we have regular testing. When we test our program, we are checking that it does not contain errors and that it works in the way that we want it to. The more testing we can carry out on our program, the less likely it is to break in the future due to a user encountering an error that had not previously been discovered.

We should be testing our program while we are building it. This way we can correctly without having to go back and change lines of code. This is a form we test our program and go back and improve it as a result of the tests that our program while we build it, we will find many of the errors as we go along errors to find and correct at the end.

We will also carry out testing on our program when we have finished buildi aimed more at testing the functionality of the system to find out whether it that were laid out when a design was developed for the program.

When we carry out anything, we must make sure testing is destructive. We program, to account for possible misuse. This misuse is not always done on someone is using the program for the first time, and doesn't know how to u

This will mean testing entering the data that an input should accept, but te other data that we do not want it to accept.

For example, let's consider the following input:

```
age ← INT( USERINPUT )
```

We have created an input that is limited to accepting only integer data. We accepts data that is of the data type integer (**normal data**). But we will also real data types or any string data types (**erroneous data**). Therefore, we ma

Test number	Test description	Test data	Te
1	Testing the input for the age variable accepts an integer data type	16	N
2	Testing the input for the age variable rejects a number that	10.2	Er
3	Testing the input for the age variable rejects a character that is a letter	A	Er
	Testing the input for the age variable rejects a string of characters	hello	Er
5	Testing the input for the age variable rejects a character that is a symbol	!	Er

This selection of data thoroughly tests our input, making sure that it should We have recorded our testing in a testing table. You will need to produce t that you carry out in your coursework. You will need to make sure that you data that should be accepted and also rejected by your program.

You will also need to test the logic of your program and test to see whether requirements have been met – this is where the fina[illegible] of data, called **bo extreme) data**, needs to be tested. This is da[illegible]ails on the boundary of data, and what is not.

For instance, you [illegible] maximum age of 100, so you would need to ch progra[illegible]tic[illegible]hen the age is set to 100. Similarly, it is impossible to b check w[illegible]ppens when you set the age to −1, or 0.

- *Normal* test *data* refers to data that the program should process nor
- *Erroneous data* refers to data that the program should not accept / c
- *Boundary data* refers to data that will fall on the edge, or boundary, been set.

Discussion point: Why do you think it is important to check data on the bo

There are different types of errors you could get in your testing. These are:

- *Syntax errors* – errors in the actual language that you are using. Th word, missing punctuation in the code or [illegible]e wrong case.
- *Logic errors* – these are hard to [illegible]t, [illegible] you end up with code not w code is written prop[illegible]y, b[illegible]omething like a wrong symbol or mat Trace tabl[illegible]ry helpful for spotting this in your algorithms.

Validat[illegible] very important technique to use when capturing data from u data entered is reasonable, so having techniques such as length checks, pre checking is vital.

Coding Challenge: Try to write an authentication routine that uses a user

Chapter Summary

- There are three main programming constructs: sequence, selection and
- When we write a program we need to apply data types to the data that data types: integer, real, Boolean, character and string.
- We store data in various ways in a program, including variables, consta
- Arrays can be one-dimensional or two-dimensional (or multidimension
- We may need to store data externally to a program; we do this using a to create and open the file to use it, and to also read and write data to a
- We need to manipulate the strings of data that we store in a prog and joining strings together.
- We can store sections of instructions that we may want to use in a pro two main types of sub-program: a function and a procedure.
- We need to ensure that when we write our code, we make it maintaina ways, including adding comments to our code and making sure that we necessary.
- We need to make sure that we thoroughly test the programs that we c program, and at the end of the program using suitable test data.
- We need to look out for syntax and logic errors in our code.
- We need to make sure that we can code different validation techniques

Exam-style Questions

1. Describe what is meant by the term 'selection'.
2. Identify and describe one difference between a record and a 1-D array.
3. Explain the difference between a syntax and a logic error.
4. Explain two ways in which a programmer can make sure that a program
5. A hospital wants a program that records and monitors the temperature of maternity unit. It wants to store the temperature of each baby; it will h

   If a baby's temperature is below 36.5 degrees, the program should alert
   If a baby's temperature is above 37.5 degrees, the program should alert

   Write an algorithm that the hospital could use to store and monitor the the unit.
6. a) A teacher needs a program that stores two test scores for each stu maximum of 15 marks and has a maximum of 20 marks. Each m any invalid data must be rejected.

      Write an algorithm that the teacher could use to store the student r ent in the class.

   b) The teacher now wants the program to be able to output the stude both tests. They also want the program to output the classes avera

      Extend the algorithm created in part (a) to include these two new re

Chapter 3: Data Representati

In this chapter you will learn:

- How to convert numbers into different representations (binary and hex
- How to measure the quantity of data (in bits, bytes, and so on)
- How to perform arithmetic on binary numbers (addition and shifting)
- How different types of data are stored on the computer (letters, images
- The need for compressing data (Huffman coding, RLE)

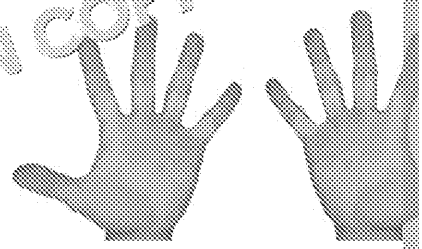
Why do computers need data in binary form?

AQA Specification Reference

- ☑ Understand the following number bases: decimal (base-10), binary (base-2
- ☑ Understand that computers use binary to represent all data and instructions
- ☑ Explain why hexadecimal is often used in Computer Science

As humans the data that we process is called **analogue** data. Analogue data is a continuous stream of data, like a sound wave or a light wave. Everything we see or hear is a continuous stream of data to our senses. Computers are not able to directly process analogue data; they need data to be in a different, **digital** form. This means that any data that we want a computer to process must first be converted into digital form. Digital data is made up of **binary** digits, that can be either a 1 or a 0. The main reason binary is used is that in the wires of a computer the voltage is either high (~5V) or low (~0V). Binary uses the base-2 number system.

As humans we usually use the base-10 number system, known as decimal (or denary). Why we count in this system is the subject of a history lesson that can essentially be put down to the fact that we have 10 fingers.



The other number system that is used particularly a lot in computer science is **hexadecimal**. This numbering system has 16 different symbols, 0–9 and A–F.

For this reason it is referred to as a base-16 system. Hexadecimal uses 16 digits the same but letters are equal to a decimal value:

0 = 0	4 = 4	8 = 8	12 = C
1 = 1	5 = 5	9 = 9	13 = D
2 = 2	6 = 6	10 = A	14 = E
3 = 3	7 = 7	11 = B	15 = F

Did you know...?

There are actually an unlimited amount of number systems. In computers there is a limit to the numbers it can represent (normally 2^{32}), so numbers larger than this are stored in base-2^{32}!

How do we represent numbers in binary and he

AQA Specification References

- ☑ Understand how binary can be used to represent whole numbers
- ☑ Be able to convert between: binary and decimal

To explain how numbers are stored in binary and he cimal, we will first we represent numbers using the number sys em h t we are most familiar w

The number 123 is made up of 3 units, tens and 1 hundred. A ten is 10 u increase by the powe each time:

	Increase by power of 10		Increase by power of 10	
Hundreds	←	**Tens**	←	**Units**
1 hundred		2 tens		3 units
1 × 100	+	2 × 10	+	3 × 1

So we can use the following table to represent 123.

$100 = 10^2$	$10 = 10^1$	$1 = 10$
1	2	3

Notice how you cannot have a value greater that 9 in any of the boxes. If t there should actually be a 0 in 'Units' box and a 1 in the 'Tens' box! This is a carry numbers in addition.

Binary

Now we are ready to learn a bout binary. Binary uses exactly the same conc hundreds we have tens, units, fours, eights, sixteens, multipling by two eac

Let us t e binary number 1001:

	Increase by power of 2		Increase by power of 2		Increase by power of 2	
	8	←	4	←	2	← 1
Binary number	1	+	0	+	0	+ 1

To convert a binary number into decimal, we do as we would for decimal, e relevant unit.

Binary number	1 eight	+ 0 fours	+ 0 twos	+ 1 o

So the binary number 1001 is 8 + 1 = 9 in decimal. 1001 is a 4-bit binary n principle to an 8-bit binary number. Let us look at a binary number 1100

Increase by power of 2	Increase by power of 2	Increase by power of 2	Increase by power of 2	Increase by power of 2	
128	←	64 ← 32	← 16	← 8	← 4 ←
1		0	0	1	0

Therefore, the binary number 11001001 when converted to decimal is 128

This is how we convert from binary to decimal. We also need to be able to do this we need to decide which binary units will need to be 1 (TRUE) to cr method we can use to do this. Let's convert the number 202 into binary.

First we write down the eight binary units we might need to use. It is easie

128	64	32	16	8	

Then we need to work out which of these units are needed. We can do this
128, and comparing it to our decimal number that we are converting. If ou
equal to this unit, then we will need it. 202 is greater than 128 so we can p

128	64		16	8	
1					

As we have subtracted the unit 128, we can now deduct this from our decimal numb
we can move to the next unit and compare it to our decimal number again, th

74 is greater than 64 so we can also put a 1 below this unit and then deduc

128	64	32	16	8	
1	1				

74 – 64 is 10; this now becomes our decimal number. We can repeat the p
which is 32. 10 is not greater than or equal to 32, so we do not use this uni

128	64	32	16	8	
1	1	0			

We can now repeat this with the next unit 16. 10 is not greater than or equal t

128	64	32	16	8	
1	1	0	0		

We move to the next unit. 10 is greater than 8, so we do need this unit and
deduct 8 from the remaining our decimal value 2:

128	64	32	16	8	
1	1	0	0	1	

We move to the next unit. 2 is not greater than or equal to 4, so we put a 0

128	64	32	16	8	
1	1	0	0	1	0

We move to the next unit. 2 is equal to 2, so we can put a 1 below it and d

128	64	32	16	8	
1	1	0	0	1	0

As we have now got the decimal value to 0, we know we do not need the u

128	64	32	16	8	
1	1	0	0	1	0

We now know that the decimal number 202 when converted to binary is 11

Quick task

Convert the following binary numbers to denary: 1) 10100011 2) 01

Convert the following denary numbers to binary: 1) 99 2) 15

Hexadecimal

AQA Specification Reference

☑ Understand how hexadecimal can be used to represent whole numbers
☑ Be able to convert between: binary and hexadecimal, decimal and hexade

We have looked at a denary number system and a binary number system so is also a number system called **hexadecimal**. Hexadecimal is a number syst uses the numbers 0 to 9 and the letters A to F. This means that it uses 16 c overall. For this reason it is referred to as a base-16 system. In a base-16 sy different unit that is used increases by the power of 16. You only need to kn hexadecimal up to two digits, so the units used will be 1 and 16. Hexadecimal the same letters are equal to a denary value:

0 = 0	4 = 4	8 = 8	12
1 = 1	5 = 5	9 = 9	13
2 = 2	6 = 6	10 = A	14
3 = 3	7 = 7	11 = B	15

The reason numbers above 9 need to be represented by a letter is because each unit in hexadecimal. For example, the number 12 has two characters with one character and this is C. Let us look at converting the denary numb we need to find out how many of the unit 16 and how many of the unit 1 w

Increase by power of 16

16 ← 1

1 × 16 = 16

2 × 16 = 32

We cannot go any higher with our workings as 3 × 16 = 48 and this is great need 2 of the unit 16. 2 × 16 is 32, so we can deduct 32 from our denary nu that we know we need 8 of the unit 1:

16	1
2	8

This means that when we convert the number 40 into hexadecimal, we get

Let's look at converting the denary number 42 into hexadecimal:

16 1

1 × 16 = 16

2 × 16 = 32

3 × 16 = 48

We cannot go any higher with our workings as 4 × 16 = 64 and this is greate
need 3 of the unit 16 and can deduct 48 from 62, leaving us with 14. This n
unit 1, but we do not write this as 14 as it is greater than 9 and has two cha
characters we looked at earlier. We said that 14 is represented by the chara

16	1
3	E

This means that when we conv[illegible]e number 62 into hexadecimal we get t

We also need to h[illegible] to convert hexadecimal into denary. To do this we
numbe[illegible]ch[illegible]e needed. Let us convert the hexadecimal value 4B:

16		1
4 × 16 = 64		11 × 1 = 11
64	+	11

Looking at this calculation we can see that 64 + 11 = 75. Therefore we kno
converted into denary is 75.

Computers do not actually process hexadecimal, they use binary. Computer
it is quicker to read than binary. Lots of 1s and 0s are needed to represent a
reduced by using hexadecimal.

Hexadecimal is used in a few ways by programmers. [illegible] application that you may know of is its use in Hypertext Ma[illegible] Language (HTML). It is used in HTML to represent colour [illegible]s. For example, the colour code for black is #000000 and the colour code for white is #FFFFFF. These are hexa[illegible]codes that are made up of six digits.

Anothe[illegible]cation of hexadecimal is in Media Access Control (MAC) addresses. A MAC address is a unique address given to each device on a network. It is used to identify the device. A MAC address is a 12-digit hexadecimal code, for example 001C626454E6.

Quick task

Convert the following hexadecimal numbers to denary: 1) A6

Convert the following denary numbers to hexadecimal: 1) 126

What operations can we perform on binary data

AQA Specification References

- ☑ Be able to add up to three binary numbers
- ☑ Be able to apply a binary shift to a binary number
- ☑ Describe situations where binary shifts can be used

Binary addition

Adding together two binary numbers is not the same as adding together two denary numbers. We have different rules that we need to follow.

There are four rules that we need to remember when adding binary numbers:

0 + 0 = 0	This is a familiar calculation that you already know
1 + 0 = 1	This is a familiar calculation that you already know
1 + 1 = 10	10 is the binary number for the denary value 2
1 + 1 + 1 = 11	11 is the binary number for the denary value 3

Let's try adding together two binary numbers using these rules:

```
  1 0 0 1 1 1 0 0
+ 0 0 0 0 1 1 1 0
-----------------
```

We start adding at the right-hand side. We know that 0 + 0 = 0, so we write:

```
  1 0 0 1 1 1 0 0
+ 0 0 0 0 1 1 1 0
-----------------
                0
```

We move one place left to the next sum. We know that 0 + 1 = 1, so we write:

```
  1 0 0 1 1 1 0 0
+ 0 0 0 0 1 1 1 0
-----------------
              1 0
```

We move to the next sum. We know that 1 + 1 = 10. We can only write one digit in each sum, so the other digit we need to carry over to the next sum. We write the right-hand digit in the sum, which is the 0. We carry the left-hand number over to the next sum, which is the 1.

```
    1
  1 0 0 1 1 1 0 0
+ 0 0 0 0 1 1 1 0
-----------------
            0 1 0
```

We move to the next sum. We know that 1 + 1 + 1 = 11. We write 1 in the sum and carry the 1 over to the next sum:

```
    1
  1 0 0 1 1 1 0 0
+ 0 0 0 0 1 1 1 0
-----------------
          1 0 1 0
```

We move to the next sum. We have a different situation now. As we have a
we do not use the 0 in the calculation. We only use all three numbers when
are 1. If a number is a 0 in the calculation it is discarded. If both numbers ar
the carry of 1. We know that 1 + 1 = 10. We write 0 in the answer section a

```
      1
  1 0 0 1 1 1 0 0
+     0 0 0 0 1 1 1 0
-----------------------
    0 1 0 1 0
```

We mov th m. We have two 0s in the calculation so we use the
1 + 0 e write 1 in the answer section:

```
  1 0 0 1 1 1 0 0
+     0 0 0 0 1 1 1 0
-----------------------
      1 0 1 0 1 0
```

We move to the next sum. We know that 0 + 0 = 0. We write 0 in the ans

```
  1 0 0 1 1 1 0 0
+     0 0 0 0 1 1 1 0
-----------------------
    0 1 0 1 0 1 0
```

We move to the next sum. We know that 1 + 0 = 1 write 1 in the ans

```
  1 0 0 1 1 1 0 0
+     0 0 0 0 1 1 1 0
-----------------------
  1 0 1 0 1 0 1 0
```

So we c e that the answer to our binary addition question is 10101010
is correct by converting all the binary numbers to their denary value:

```
  1 0 0 1 1 1 0 0      = 156
+     0 0 0 0 1 1 1 0  = 14
-----------------------
  1 0 1 0 1 0 1 0      = 170
```

We can see that our addition is correct as 156 + 14 = 170.

Let's try adding two more binary numbers, 11000110 and 10101111:

```
  1 1 0 0 0 1 1 0
+     1 0 1 0 1 1 1 1
-----------------------
```

We can use the rules a d add each sum together and we will get:

```
      1 1 1
  1 1 0 0 0 1 1 0
+     1 0 1 0 1 1 1 1
-----------------------
    1 1 1 0 1 0 1
```

We get a problem though when we get to the last sum. We need to add together 1 and 1; this will give us 10. We write 0 in the answer section, but still have 1 to carry. We cannot carry the one to another sum though as we do not have any left. This 1 becomes what is known as an **overflow error**:

Overflow error → **1**

```
  1 1 0 0 0 1 1 0
+ 1 0 1 0 1 1 1 1
-----------------
  0 1 1 1 0 1 0 1
```

An overflow error occurs because our number after addition becomes too big stated earlier that the largest number that could be stored in an 8-bit byte is numbers to their denary value and add them together, we will see that they

```
  1 1 0 0 0 1 1 0      =  198
+ 1 0 1 0 1 1 1 1      =  175
-----------------
  0 1 1 1 0 1 0 1
```

We can see that 198 + 175 = 373. This is larger than 255 so it creates the

Binary shifts

A binary shift can be performed on a binary number. It can be performed to of data. In a binary shift all the numbers in the binary number are shifted to of places. Zeros are added to fill the places left by the shift. The out of the byte are discarded.

Example of a left shift

Let's use the binary number 00110011. We will perform a left shift of two p

If we perform a left shift of two places, each digit in the binary number gets two digits at the left of the number are discarded. Two zeros are placed in t We can show this in stages:

Original binary number:

0	0	1	1	0	0	1	1

Each digit shifted two places right:

1	1	0	0	1	1	0	0

Zeros replace empty spaces
Digits shifted out are discarded:

1	1	0	0	1	1	0	0

11 discarded

A binary shift affects the denary value of a binary number. If we convert the 00110011 = 51

After we have performed the two-places-left shift, the value of the denary n 11001100 = 204

Although you don't need to know this, the notation used for a left shift is '<< 51 << 2 = 204.

Example of a right shift

Let's use the binary number 00110011 again. We will perform a right shift o

If we perform a right shift of two places, each digit in the binary number ge
The two digits at the right of the number are discarded. Two zeros are place
shift. We can show this in stages:

Original binary number:

0	0	1	1	0

Each digit shifted two places to the right:

		0	0	1

Zeros replace empty spaces
Digits shifted out are discarded:

0	0	0	0	1

If we convert the first binary number to denary we get:
00110011 = 51

After we have performed the two-places-right shift, the value of the denary
00001100 = 12

Right shifts also have their own notation '>>'; in this case 51 >> 2 = 12.

Quick task

Perform a three-place binary shift to the left on the binary number 10110

What effect has this had on the denary value?

How can we measure the size of data?

AQA Specification References

- ☑ Know that a bit is the fundamental unit of information, and a byte is a gro
- ☑ Know that quantities of bytes can be described using prefixes

When we store a file it takes up a certain amount of storage space. We call th
amount of data a storage device can store its storage capacity. We may want t
how big it will be to store. Most computers will do this for us, but it is useful t

To calculate the size of a file we need to know how data is measured. To m
following units:

Name	Unit	Capacity
Bit	bit	1 bit
Nibble	nibble	4 bits
Byte	byte	8 bits
Kilobyte	KB	1000 bytes

Name
Megabyte
Gigabyte
Terabyte
Petabyte

Note: A bit is the smallest possible unit we have available, and corresponds
stores either a 1 or a 0.

How is binary used to represent characters?

AQA Specification References

- ☑ Understand what a character set is and describe the character encoding m
- ☑ Understand that character codes are commonly grouped and run in sequen
- ☑ Describe the purpose of Unicode and the advantages of Unicode over ASC

Computers can only process binary; therefore all data we input into a computer needs to be converted into binary.

We have looked at converting number into binary; we also need to understand how text, images and sound are converted into binary.

If we had to write in binary to create all the documents we needed to create, such as our homework or messages to our friends, it would take us a great deal of time. Typing out the 1s and 0s that are needed for each character would take much longer than typing any character the binary numbers represent. This is why binary codes were created to represent each character, so that we can just press the character on our keyboard and it is converted into binary, so the computer understand which character we have pressed. The character will then appear in our document or message.

Each character is assigned a different binary code. Capital letters and lowe binary codes, as will punctuation and numbers. All other keys on a keyboar assigned to them, such as ALT and SHIFT.

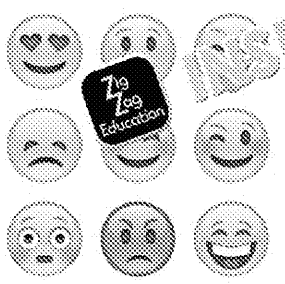
What is a character set?

The binary code that is used to represent each character is called a **characte set**. There are two main character sets that are used: ASCII and Unicode.

ASCII stands for American Standard Code for Information Interchange. It w based upon the English language. In ASCII, each character is 1 byte of data up of 7 bits and there is a 0 present at the start of each to create the byte o ASCII; these are the numbers 0 to 9, the lower-case letters a to z, the capita symbols, the space bar and other keys present on a standard keyboard.

You can easily search for an ASCII conversion chart on the Internet. It will s character; for example: a = 01100001 A = 01000001. You will also see that = 01100010 and B = 01000010. The groups work in sequence so ASCII 'A' is should be able to work out 'F'.

There are some languages that use a completely differ t alphabet to the E would not be possible to use ASCII to create the additional characters needs Therefore another character set was created called Unicode.



Unicode was developed in the late 1980s when it a lot more characters to have a universal characte used in ASCII can only represent up to 128 charac for each character, which means that more than 6 This is more than enough for every language to be As well as the letters for each language, there is s icons that convey various emotions, and commonly communication platforms such as instant messagi

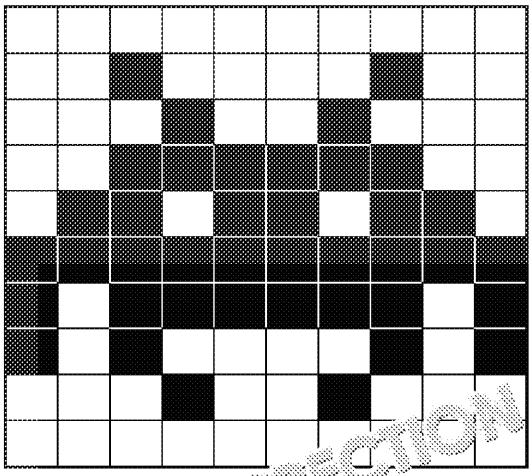
How do we represent images using binary?

AQA Specification References

- ☑ Understand what a pixel is and be able to describe how they relate to an i
- ☑ Describe the following for bitmaps: size in pixels and colour depth
- ☑ Describe using examples how the number of pixels and colour depth can a
- ☑ Calculate bitmap image file sizes based on the number of pixels and colou
- ☑ Convert binary data into a black and white image and vice versa

We regularly take photographs with our digital devices, but how are these i computers? We see these images as analogue, but as we have stated previous convert them to binary to be able to process and store them.

Images are made up of **pixels**; these are tiny squares that appear on a screen Each of these pixels has a binary representation. If an image is simply black and white in colour, then each pixel would be a 1 or a 0; for example:



In this image 1 represents The binary code for this i

```
0000000000
0010000100
0001001000
0011111100
0110110110
1111111111
1011111101
1000000101
0001001000
0000000000
```

In order to calculate the size of a bitmapped image we need to know two pr (image size) and the colour depth.

The number of pixels can be found easily by multiplying the number of row colour depth can be found by calculating the minimum amount of bits need

In this case, we have a 10x10 image, with a colour depth of 1 bit – there is bit to store it. So in total, our image has a size of 100 bits.

To calculate the file size needed to store an image, you use the formula:

file size = number of pixels × space needed to store one pixel

We have to be able to calculate sizes in bits and bytes.

W = Image Width
H = Image Height
D = Colour Depth in bits

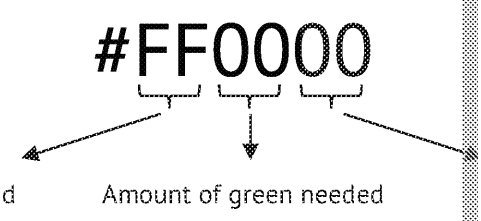
Size (bits) = W x H x D

Size (bytes) = W x H x D/8

How can the number of pixels and the colour de an image?

If we want our image to be more than just two colours, each pixel needs to This extra binary data will instruct the computer on how to create the colou colours are made up of red, green and blue; this is call the RGB colour sy blue needed to make up the colour will be re e the binary data for e shortened to their hexadecimal form as they are easier for us to use.

An example of a colou is #FF0000. The code is broken up into the fo



This is the colour code for red; as you can see, it needs the full amount of r converted this hexadecimal number to binary it would be 11111111000000 red, green and blue, is represented by a byte of data. All this data is neede image. Thousands of pixels are normally needed to create an image, theref bytes) of data, that's a lot of data to create an image!

The size of an image file can be affected by the amou f data that needs that needs to be stored is affected by the qu and size of the image. If a would allow for four different value used, 00, 01, 10 and 11, giving f the number of bits that are used p ixel, the more colours can be made a would allow 256 c be used. The system we spoke of above uses a millio le colours per pixel. Therefore the greater the colour depth, create age.

The number of pixels directly affects the physical file size; the more pixels

How is sound represented using binary?

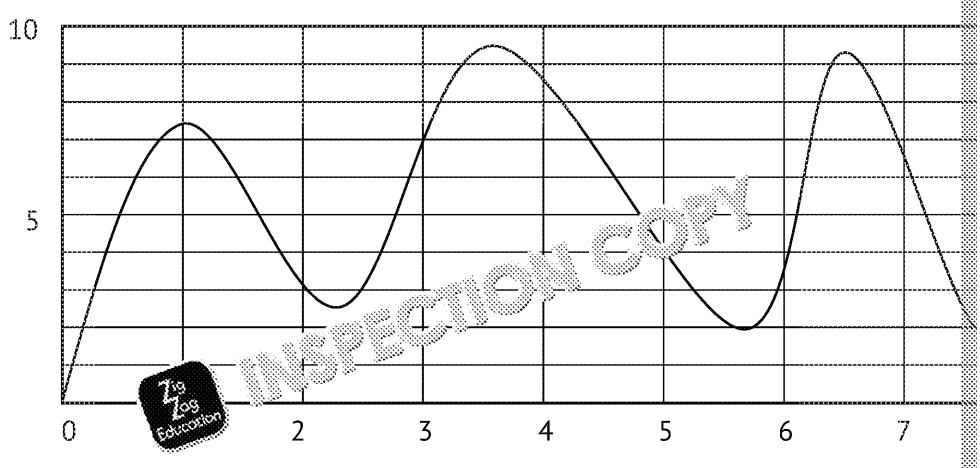
AQA Specification Reference

- ☑ Understand that sound is analogue, and it must be converted to a digital f
- ☑ Understand that sound waves are sampled to create the digital version of

Although sound is made up of one continuous wave, we an also store it di way of converting sound into binary to be abl p ess and store it using

When we record sound we do th s t me intervals; this is called **sampling**. When we s w are meauring the **amplitude** of the sound w T ng rate is measured in hertz (Hz); 1 Hz means 1 samp n per second. Most music CDs are sampled at 44,100 Hz.

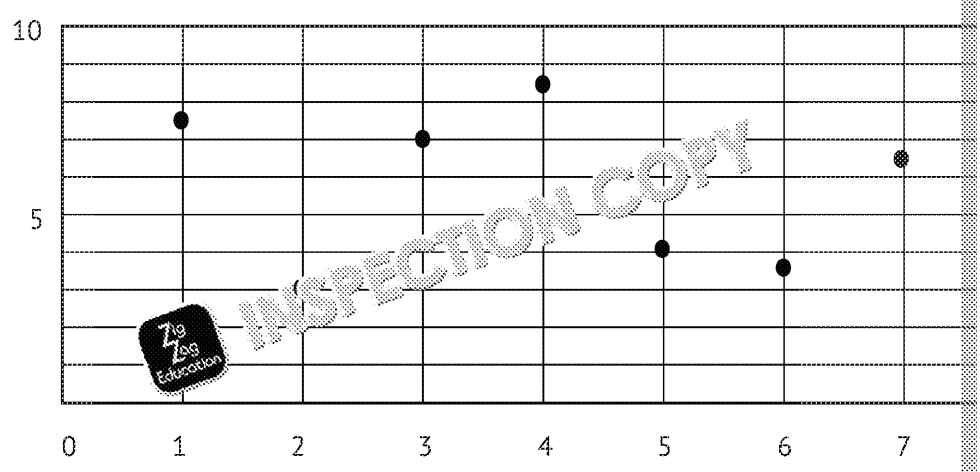
We can look at how a simple sound wave is sampled:



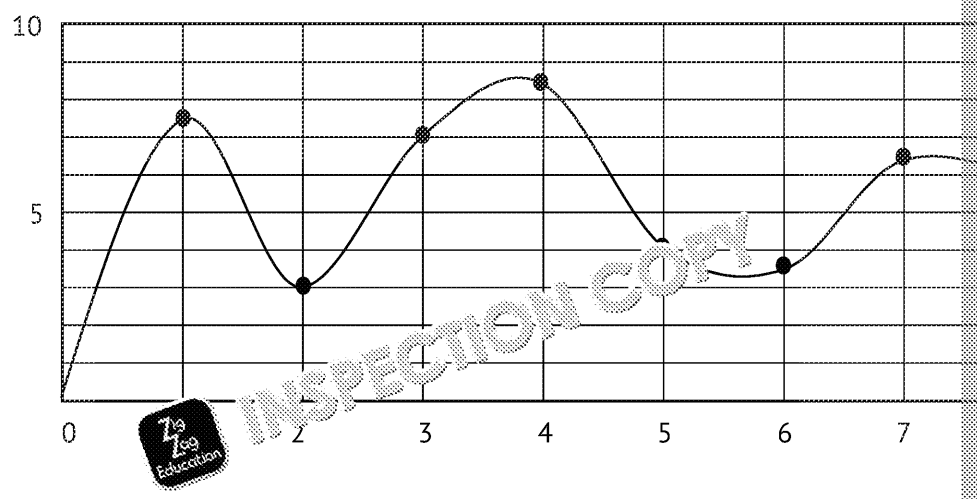
We can record the sound value at each sample taken:

Amplitude	7.5	4	7	8.5	4	3.5	6.5
Time sample	1	3	3	4	5	6	7

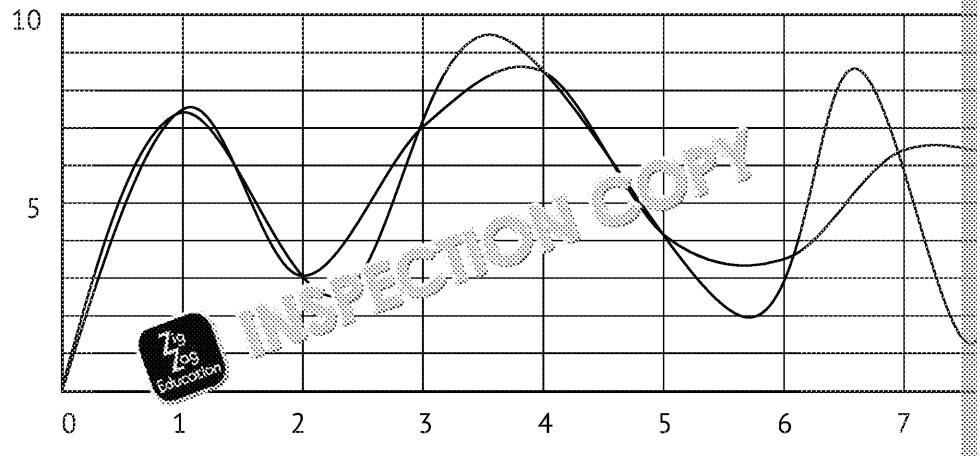
These values are converted to binary and stored in the sound file. When the values are used to recreate the analogue sound. We can use the samples we



We can then create the sound wave using these sample points:



If we overlay the original sound wave with the one played back after record
difference between the two:



This difference occurs because the computer can only recreate and playbac
It doesn't know what has happened between each sample as it hasn't recor
the sound wave in particular, it fluctuates up and down quite a bit in betwe
hasn't recorded this so it just interprets it as a steady decline in the sound w

How can sampling rate and resolution affect the

AQA Specification References

- ☑ Describe the digital representation of sound in terms of sampling rate and
- ☑ Calculate sound file sizes based on the sampli[illegible]e and the sample reso

The frequency at which the sound is sampled in a sound recording can affe
sound is output. This is called the **sampling rate**. If a small sampling rate is
one above, then fluctuations in the original sound may not be recorded at a
increase the accuracy of the sound that is output we can increase the sampl
look at the sound wave above and double the number of time samples take
a more accurate sound wave when output. Try it and see!

The closer together the time samples, the more accurate the sound that wil
recorded with a sample size of 44,100 hertz. It is important that the output
original sound recorded. Telephone conversations are sampled at a lower r

Discussion point: Why are telephone conversations sampled at a lower ra

The higher the sampling rate for a sound file, the larger the file will be. Th
samples to store.

The sample resolution can also affect the size of a sound file. The sample r
refers to how many values can be measured on it. A 2-bit sample resolutio
give four values to measure; an 8-bit sample resolution would give 256 val
measure. Most CDs use 16-bit sample resolution. The more values that ca
measure, the more data that can be recorded and the larger the file size.

To calculate the file size needed to store a sound clip, you use the formula:

file size = length in seconds × number of samples taken per second ×

So a 10 second long clip, with a sampling rate of 100Hz, and a sample reso
size of 10×100×4 = 4000 bits = 500 bytes.

Why is data compression important and how do

AQA Specification Reference

☑ Understand what data compression is, why data may be compressed and t

Sometimes a file may be too big for us to store, or too big for us to downlo transmit to someone else. We may want to reduce t ze of a file or a nu to reduce the amount of storage space used on our hard drive, or to make d or transmitting a file quicker. We can do this by using file compression.

When we compress da manipulate the structure of the data to make t the file s ler compression algorithm is used to do this and there are t types o ithm used: lossy and lossless.

Lossy compression

Lossy compression reduces the size of a file by permanently removing some data in the file. The data that is removed is often thought to be redundant o make only a small difference to the quality of the file. When the file is resto was removed during the compression process cannot be restored.

Lossy compression is mainly used for audio, video and image files. It is mo files when streaming or transmitting them – however, there might be times this exactly the purpose of lossless compression.

Example: *James has an audio file that he wants to send to Sabina for her to a wants to reduce the size of the file so that it is small enough for him to attach t compress the file into an MP3 format. MP3 uses lossy co ession to reduce th removing background noise and any sounds tha ou not be heard by the hu the size of the file, but it will be difficult to tell when listening to the audio file still be a very close representa .*

Lossl m ession

Unlike compression, **lossless compression** does not remove any of the original data from the file to reduce the size of it. When lossless compression is used to reduce the size of a file, the file can be restored to the original form. Lossless compression is used when it is vital that the file is restored to its original form and that no data is lost algorithms that work in different ways.

Los doe dat

Example: *Marcus has a text file that he is using to store the following quote: 'As ask what you can do for your country'. Marcus wants to compress the file so it tak possible, but he does not want to lose any data from the file to do this. He uses l*

Excluding spaces and punctuation, the message has 61 characters. Each charac means we would need 61 bytes of storage to store this q e.

If we look at the quote it has repeating words i it. W ould store the words us they occur in a lookup table:

Word	Posit
as	1, 10
no	2
what	3, 11
your	4, 16
country	5, 17

Word	Position
can	6, 13
do	7, 14
for	8, 15
you	9, 12

When we compress d store each character position of the word. would be 49 bytes. T we have saved 12 by seem a great deal, bu saving would be muc

How do we use run-length encoding and Huffm

AQA Specification References

- ☑ Explain how data can be compressed using Huffman coding and be able to
- ☑ Be able to calculate the number of bits required to store a piece of data co
- ☑ Be able to calculate the number of bits required to store a piece of uncom
- ☑ Explain how data can be compressed using run-length encoding (RLE)
- ☑ Represent data in RLE frequency/data pairs

Run-length encoding

Run-length encoding is most useful when data repeats itself often. This im
suited – as there aren't many many words that contain more than tw
to each

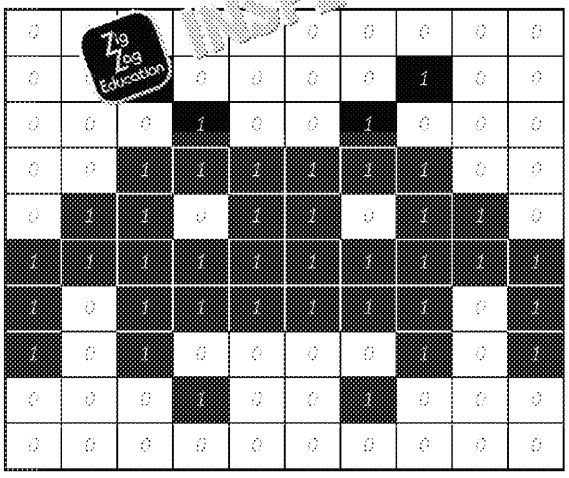
Suppose we were compressing the string "AAAAABBBCCCCDDE". This can b
a character is repeated, and then storing that number with only one copy o
be 5A3B4C2D1E. In the original string, 105 bits are needed for storage. Us
bits, as each letter is stored once (taking 35 bits of space), and in total 11 b
of occurrences of each character.

Now, suppose we compressed the string "ABCDEABCDEABCDE". This is a ba
the file size (the compressed string would be "1A1B1C1D1E1A1B1C1D1E1A

Note: *The number of bits needed to store an uncompressed ASCII string is 7 x*

Run-length encoding tends to work better for images, although it's effectiv
being compressed. Images with long runs of pix[illegible] the same colour will
than images that have a number of diff[illegible]nt colours that change frequently

Below shows how the data for a bitmap would be compressed using RLE.



(10x0)
(2x0) (1x1) (4x0) (1x1) (
(3x0) (1x1) (1x0) (2x1) (
(2x0) (6x1) (2x0)
(1x0) (2x1) (1x0) (2x1) (
(10x1)
(1x1) (1x0) (6x1) (1x0) (
(1x1) (1x0) (1x1) (4x0) (
(3x0) (1x1) (2x0) (1x1) (
(10x0)

Note: *Each item is stored as a* ***value pair*** *with the first number being the "run l
the binary code and the second number being the "encoding" or binary code for*

*In the example given the colour depth is only 1 bit as one bit is being used for e
were 2 bits per pixel the colour code would be either 00, 01, 10 or 11.*

Huffman coding

Huffman coding is much more efficient at compressing data – it is an exam
where some letters are compressed more than others. The main idea is tha
about the order of data, but instead the *frequency* of data. The most freque
codes, so in theory the compressed data will be as short as possible.

Example: Imagine a 500 character document sto 7 bit ASCII. This wo
using any compression. We will now h a look at how this would be stor
(represented using a Huffma

For this exampl l assume the document only contains the letters a,
extend ar ple to include all of the characters in the document.

Step 1: *Create a frequency table and sort it with the lowest frequency first.*

Frequency	Character
10	b
20	c
40	d
150	a
280	e

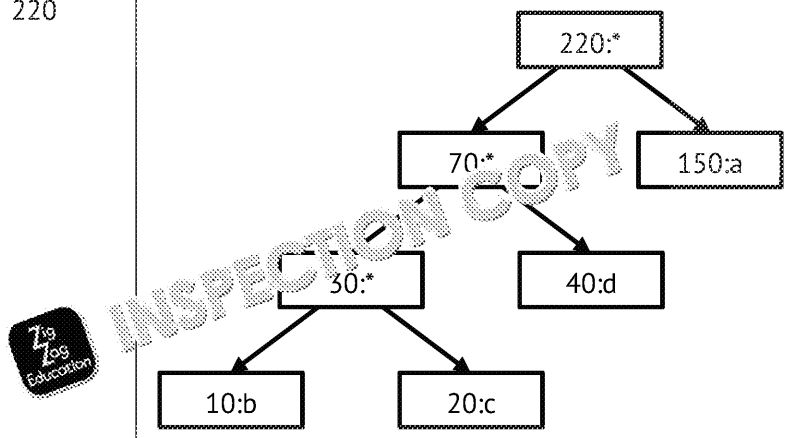
Step 2: *Create a tree with the two lowest frequency elements as leaves.*

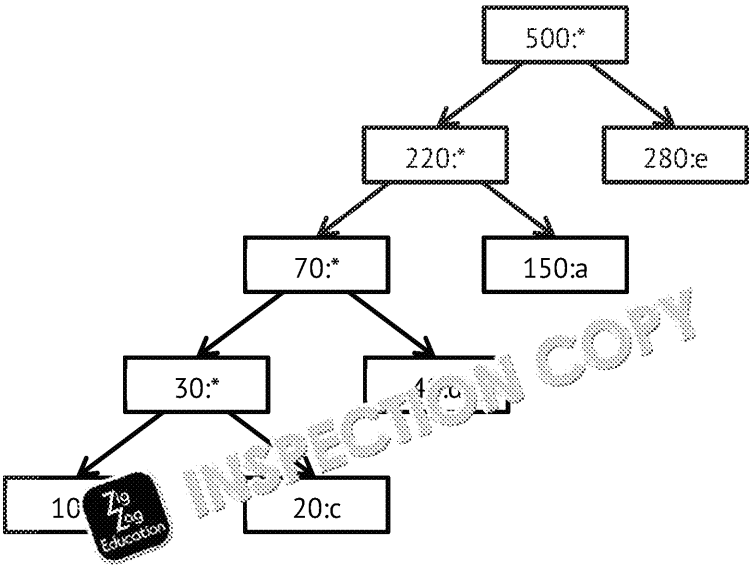
Step 3: *Put this tree back into the table in frequency o .*

Frequency	Cha t
	30:* 10:b 20:c
40	d
150	a
280	e

Step 4: *Repeat steps 2 & 3 until there is a complete tree containing all of the e*
(and therefore a table of only one row). This process is shown below.

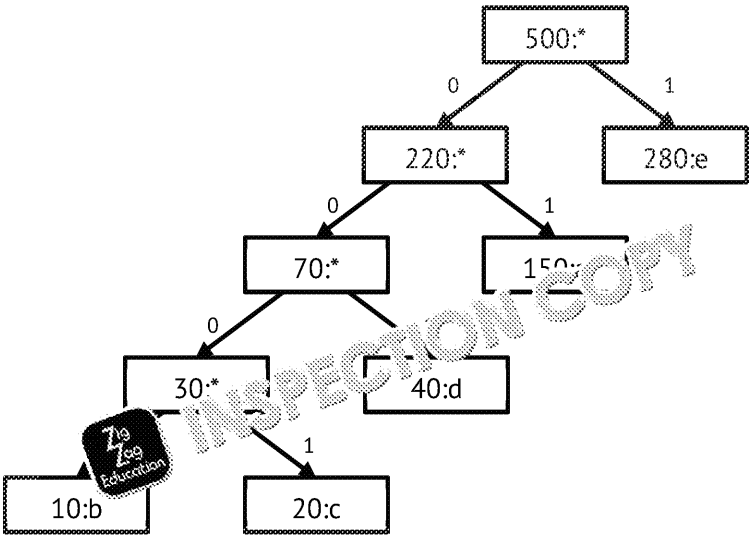
Frequency	Character
70	70:* 30:* 40:d 10:b 20:c
150	a
280	e

Frequency	Character
220	
280	a



The tree is now complete.

***Step 5**: Now you traverse the tree always allocating a 0 when you go left and a*



Step 6: Put the letters back into the table so that you can see how each letter is

Letter	Encoding
e	1
a	01
d	001
c	0001
b	00000

Step 7: Calculate how many bits it will take to store the file.

Letter	Encoding	Bits Used	Frequency	Total Bits
e	1	1	280	280
a	01	2	150	300
d	001	3	40	120
c	0001	4	20	80
b	00000	5	10	50

Adding up the *Total Bits* column gives us 830 bits which is a lot lower than t standard ASCII would take. As you can see, because the low frequency lette and the highest frequency letters using the fewest bits, this encoding is ver

The big question: **So why does Huffman coding work?**

Imagine if the final file were just the word: "aced", this would be stored as:

0100011...

This works because there is only one interpretation for each code in the file you read in 0 and that doesn't represent a letter so you keep reading and yo the codes, they all start with a number of zeroes, so all you have to do is ke you have your next letter.

Discussion point: In this example, how many bits are saved using Huffma

RLE vs Huffman trees

The choice of compression method depends on the scenario. If an image is more sense to use RLE, as blocks of the same colour tend to be next to each definitely not work due to the total number of possible colours. For text, Hu RLE tends to work better when there are lots of repeating patterns, somethi written text.

Run-length encoding	
Pro: Works well for images that have blocks of the same colour and text that has repeating symbols.	**Pro:** Compress tex
Con: Isn't ideal for text written in English, compression string can often be larger than the actual string.	**Con:** Huffman tree that is compressed different string mi

Chapter Summary

- We process analogue data but computers process digital (binary) data. converted to binary to be processed by a computer.
- There are different number systems that we need to know to convert d to hexadecimal. Decimal is a base-10 system, binary is a base-2 system base-16 system.
- A binary shift can be performed on a binary number. The shift can either affect the decimal value of the number.
- The text-based characters that we use every day need to be represented computer. The computer knows what the character selected is by the
- Images are made up of pixels. The amount of data needed for each pix image or black and white. If the colour depth and pixel size of an imag size of the image file.
- Sound is sampled at set time intervals when it is processed by a comput rate. If the sampling rate is increased, this will increase the size of the increased if the sample resolution is increased.
- Files can be compressed. A compression algorithm can be used to do t trees and run-length encoding.

Exam-style Questions

1. Convert the binary number 10110001 into decimal. Show your working
2. Convert the binary number 10110001 into hexadecimal. Show your w
3. Convert the binary string 0110100101101001 into a 4×4 image, with a
4. The character M has is represented using the code 01001101 in ASCII. State the ASCII representation of the letter P.
5. Calculate the file size of a 10 second sound clip, with a sampling rate o resolution of 8 bits. Give your answer in bytes.
6. Which method of compression would be most appropriate for compres Explain your answer.
7. Explain two ways in which the quality of the playback of a sound file c
8. Create a Huffman Tree for the string "SMALL".

Chapter 4: Computer System

In this chapter you will learn:

- The difference between hardware and software
- The different types of programming language and translators
- Logic gates (NOT, AND, OR, XOR), truth tables and logic circuits
- The architecture of modern computers, the purpose and function of the CPU
- The differing types of secondary storage (solid state, optical, magnetic), and
- The difference between general purpose computers and embedded systems

What is the difference between hardware and s

AQA Specification References

- ☑ Define the terms hardware and software and understand the relationship b
- ☑ Explain what is meant by system software and application software.

Computers can be split roughly into to halves – the physical components that make up the computer called the **hardware**, and the programs that we run using the hardware – called the **software.**

There are two main types of software that are used on computer systems; these are **systems software** and **applications software**.

Systems software controls the operations of hardware in a computer system. These are programs such as disk defragmentation and file encryption; their only purpose is to assist with the operation of the computer.

Applications software is the everyday programs we use to create documents and carry out communication with each other using technology. Some examples include Internet Browsers such as Internet Explorer, Graphics Software such as software such as Microsoft Word.

Discussion point: Can you think of any examples of system software?

What roles are performed by the operating syst

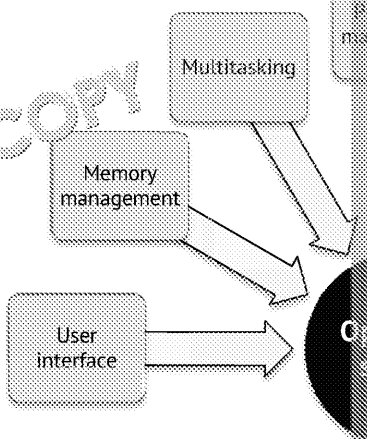
AQA Specification Reference

- ☑ Understand the need for, and functions of operating systems (OS).

An **operating system** (sometimes shortened to the initials OS) is software that is loaded by the computer after the initial boot-up.

Once loaded, the operating system controls the operations of the hardware in a computer system and manages all other software.

The operating system provides a number of important functions for the computer.



The different functio

Without an operating system we would not able to use a computer. This is b
command the hardware to carry out any processes or run any software to car
provides us with the ability to interact with a computer system. The way a us
system is through the use of a user interface.

User interface

The **user interface** is what we use to interact with a computer.
There are three main types of user interface: graphical, command-line and natural-language.

Graphical User Interface (GUI)

A graphical user interface (GUI) is the most common type of interface we use
interact with computers. This is the type of interface that has lots of icons, m
and windows for us to click and open. We use this type of operating system o
many devices including our personal computers, smartphones and tablets.

A GUI has lots of helpful guidance and clear items for us to interact with in o
to carry out the daily tasks we use our computer for. We do not need to type
any commands to carry out tasks, just click the icons and menus to do so.

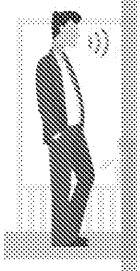
Command-line Interface (CLI)

A command-line interface (CLI) is another type of user interface. This type o
menus to guide the user to perform tasks; it requires the user to type in the
that they want to perform. This type of interface is what people had to use
GUIs were developed. Some people still use CLIs as they like to be able to
computer as they wish, rather than having to use pre-programmed com

The user needs to ha
they can use in orde

An example of a CLI
let you use your com
line – you can still r
as you would with a

Natural-language Interface (NLI)



The third main type of user interface is a natural-language interface (NLI). A user controls a natural-language interface through the use of commands that are often spoken. The user can make use of common phrases to interact with the computer and perform tasks.

However, in practice, the ability of a NLI to understand most commands can often be ambiguous and can frustrate the user. A common NLI makes use of natural-language processing to answer questions, perform

Memory management

Managing the memory of a computer is a function that is carried out by the
manager refers to the managing of the computer's **primary memory**. Th
each and every memory location to see whether it is in use or available to b
much memory needs to be allocated to a process and decides which proces
one time. If the operating system does not manage the memory effectively
ability to perform tasks.

Multitasking

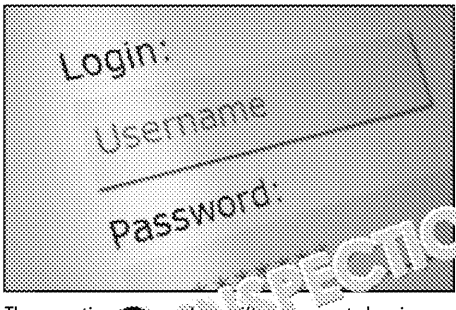
The multitasking function in an operating system allows a computer to run many applications at a time. It is multitasking that allows you to listen to music on your computer, while doing your homework and surfing the net all at the same time. The operating system is able to keep track of where you are up to with various applications, as you move from one to the other, without losing any data. There is a limit to how many applications an operating system can handle at any one time.

The more applications a user has open, the slower the operating system will be to manage all of them.

Peripheral management and drivers

The peripheral management function of an operating system controls the co peripheral devices that are linked to the computer system. Example periphe and a printer. The operating system handles the input from and the output t sending and receiving commands from them in their programmed language

Each peripheral device that is attached to a computer system has a softwar interaction; this is called a driver. The operating system needs these drivers with the peripheral device. Drivers devices and downloaded onto a co first connected to the computer sy



The operating system allows different users to be given a username and password to log on to a computer system

User management

The user management function of a users to be able to log on to a com that logs into the system to do so also manages the data and applica these are normally identified from

File management

File management is the function that the operating system uses to organise and keep track of files stored on a computer system. As far as a computer is concerned, all that exists in the computer's memory is blocks of data. It is the file management function that allows the user to see the data in the secondary storage (either a magnetic hard drive or a solid-state drive) in the form of structured files and folders.

The

What is utility software and why do we need it?

AQA Specification Reference

☑ Understand the need for, and functions of utility programs.

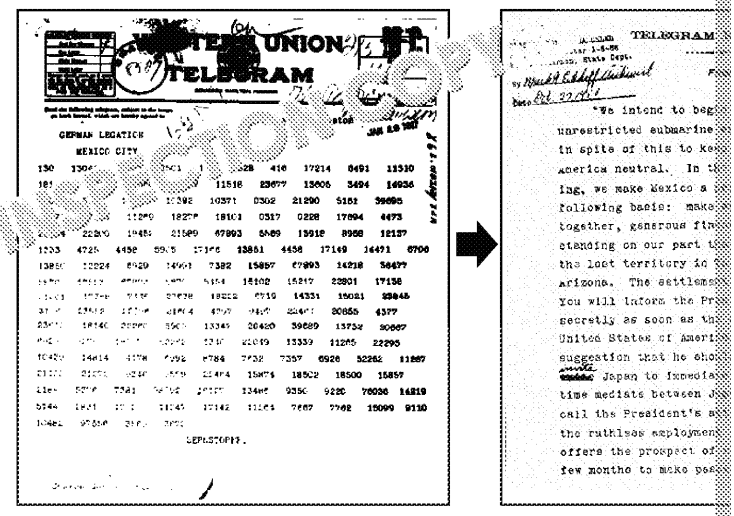
Utility software is a type of systems software. It helps manage, maintain an
Most utility software is designed to carry out a si[illegible] task, or very small n
into the operating system, but it can also be installed as a separate program
alternative to the one offered by the operating system.

Tasks that utility software may be responsible for include:

- [illegible]onversion
- File repair
- Encryption
- Defragmentation
- Data compression (*see Chapter 3*)
- Backing up data
- Antivirus

Encryption software

Encryption software is used to encrypt data. When data is in its original for
encryption software uses an encryption algorithm and an **encryption key** to
data has been encrypted it is referred to as **cipher text**. The cipher text can
the correct encryption key. People mostly encrypt data to store it or transm
we send any details to our bank, the data is encrypted before transmission.



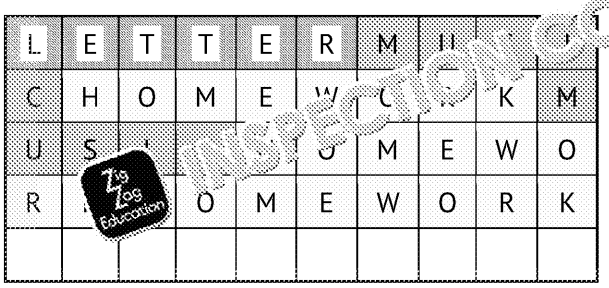
Zimmermann Telegram issued from the German Foreign Office in Ja
Left shows the encrypted message (cipher text). Right shows the message after it was in
British and sent to the US government.

There are two main types of encryption: symmetric a[illegible]symmetric. In symm
encryption key is used to encrypt and decrypt the data. Symmetric encryptio
but the key needs to be sent with the data for the receiver to decrypt the data
the encrypted data is intercepted during transmission, the interceptor will ha

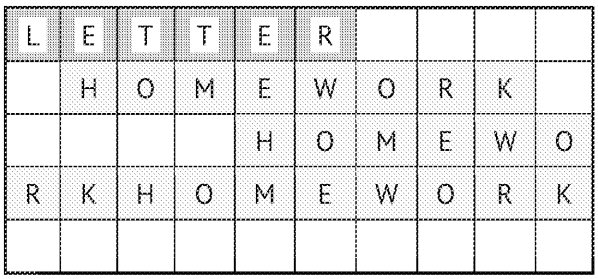
In asym[illegible]ic [illegible]on, a different key is used to encrypt and decrypt the
public [illegible]ich everyone can see, and a private key, which only you have
Alice to send Bob an encrypted message, she must first encrypt her messag
everyone can see), so only he can decrypt it using his private key (that only

Defragmentation

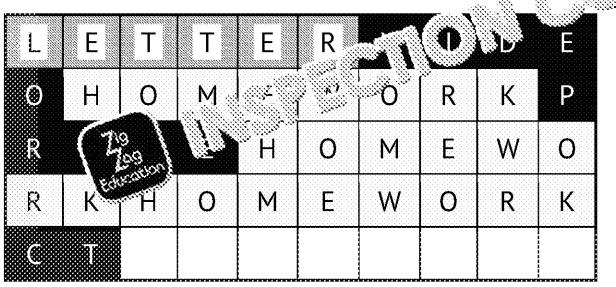
When data is stored on a computer's hard drive, the computer doesn't look f
the data can be stored in full and continuously. It breaks the data up and st
the hard drive. Available space on a hard drive is often as a result of chang
example, Alice has six files stored on her hard drive. These are a letter, thr
music files. Her hard drive looks like this:



Alice decides that she no longer needs the music files, so she deletes them

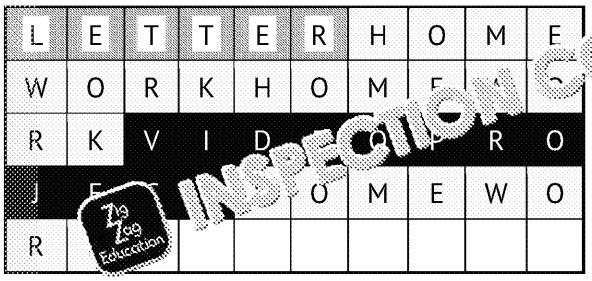


This leaves Alice with some free space on her hard drive. Alice now needs t
The computer will find the next available spac[illegible] ard drive to save t



The video project file was broken up into fragments to be stored in the ava
fragmented hard drive. She can run defragmentation software that will help
bring together any fragmented files. To do this the software will move arou
to join together any fragmented files. When files are not fragmented, it ma
as the computer does not have to search for the fragmented parts of the file

After running defragmentation software, Alice's hard drive might look like t



All the file fragments have been joined together and the hard drive is no lo

Methods of backup

Backing up is the process of making and storing copies of files in case of eq
that could cause loss of data. Files are backed up in the event that the data
at any time.

In a full backup, all the files and folders selected for backup will be backed up. This type of backup is normally carried out as an initial backup of files, as all of the files will need to be copied. This kind of backup can take a long time to be completed, especially when there are lots of files to be backed up.

Large
dedi

For this reason, once an initial backup has been carried out, people may want to just back up the files that have changed since their last backup. This type of backup is called an incremental backup. This type of backup will only back up the files that have changed since the last backup was carried out. This can make the process of backing up on a regular basis much quicker.

What are 'high-level' and 'low-level' programmi

AQA Specification References

- ☑ Know that there are different levels of programming language.
- ☑ Know that machine code and assembly language are considered to be low
  the differences between them.
- ☑ Understand the advantages and disadvantages of low level language prog
  level language programming.

A computer programming language can be categorised as either a **high-level language** or a **low-level language**.

High-level programming languages are the languages that most people use
program. They use language statements and commands that are close to w
we use on a daily basis as humans. They are much easier for users to read a
write programs in. Examples of high-level languages would include Python
JavaScript and Visual Basic.

Low-level programming languages are much closer to the language that a computer understands. Examples of low-level languages would be assembly code is literally the 1s and 0s that a computer can understand, whereas assembly mnemonics, to assign meaning to the 1s and 0s. For instance, a machine code that increments a value by 1. Now this isn't particularly readable – with assembly such as `INCR a`. When the assembly code is run, this gets translated directly representation (it might be the case that INCR = 0110 and a = 0001).

In the early days of computing, computers were programmed by writing **machine code** by hand. This had the advantage of allowing the programmer directly control the computer by directly referencing memory addresses and computer registers. To aid programmability the instructions were written in binary. However, machine code is very difficult to read and so even an experienced programmer will struggle to understand a large piece of code without a significant amount of

This led to the development of **assembly code**, which replaced the hexadecimal instructions of machine code with mnemonics which were eas to understand. Most assemblers also allowed the use of symbols (or variables) signify memory addresses which would be referen to a memory address by the assembler. Assembly language, however, still operates at a very low lev and becomes more and more difficult to use as programs become larger.

Assembly code – low-level language which uses mnemonic codes to represent machine code

One of the big problems with assembly language is the use of *GO TO* statemen sequentially executed statements can be changed at will. Structured prog addresses these issues, providing a level of abstraction away from the ope code shorter and far easier for humans to understand.

Structured programming involves writing statements that are executed in s constructs such as iteration, selection, functions and procedures. The adva the fact that it becomes just so much more readable for programmers.

Did you know?!

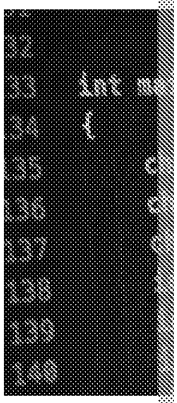
The original version of the game RollerCoaster Tycoon was written by one person code was written in an assembly language!

In a low-level language each line of code will perform only one task. In a h can perform many tasks. Low-level language is still used to program certain hardware.

A very basic example has been given using each level of language:

High-Level	Assembly	Machine code
a ← 1 b ← 2 c ← a + b OUTPUT c	STO a 1 STO b 2 ADDR c a b OUT c	01010001010100101100

You can see that the high-level example is incredibly clear, the assembly code is only clear if you understand the mnemonics used, and the machine code is completely unreadable. This is why high-level languages are often used over low-level languages. This doesn't mean that low-level languages shouldn't be used – there are often advantages to using low-level languages:



High-level code is e is a series of 1s and

- Lower-level languages give more control over the computer's registers (see Chapter 4), which allows for more optimised code.
- Useful in systems designed for microprocessors (*embedded systems* in Chapter 4).
- Code is run directly; there is no intermediate stage between the sou
- You get complete control over your code and the machine that it is

Of course, in most cases high-level languages are preferred, mainly because

What are program translators?

AQA Specification References

- ☑ Understand the three common types of translator.
- ☑ Explain the differences beteen the three types of translator.
- ☑ Understand when it is appropriate to use them.

Computers only understand 1 and 0, so it is important that we have some w
translating the code that we use to make understandable by the compute

There are three com or translator that can be used:

- re – these call machine code subroutines to carry out the
mands. They go through the code a line at a time, translate it a
found, the code stops.
- *Compiler* – these translate the high level code into machine code di
and then run. After compiling all the code error messages are gene
Anyone buying software that has been compiled will not need the t
software. It produces an executable file that can run on any machi
- *Assembler* – these translate code written in assembly language dire

Discussion point: When would it be appropriate to use these different tra

How are logic gates and circuits used?

AQA Specification Referenc

- ☑ Construct truth tab th following logic gates: NOT, AND, OR, XOR.
- ☑ Const s for simple logic circuits. Interpret the results of sim
- ☑ C d interpret simple Boolean expressions.

Most of the hardware of a computer is made up by **logic gates**. A logic gate is
foundation block of a digital circuit; it controls the flow of electronic signal
digital circuit. One or more inputs will flow into a logic gate and one outpu
flow from the logic gate. The inputs into the logic gate and the logic of the
determine what the output will be.

The **voltage** of the electrical signals flowing into and out of a logic gate can
or low. If the voltage is high, it is represented by the binary digit 1. If the v
low, it is represented by the binary digit 0.

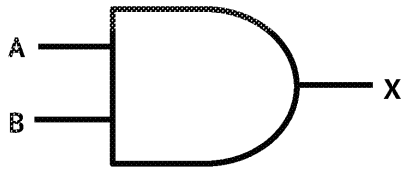
Some logic circuits only need a few logic gates; others, such as a **microproc**
require thousands.

There are various logic gates that a an output that depends on the in
We are going to look at e following gates:

- ga
- te
- NOT gate
- XOR gate

AND

The AND logic gate is represented by the symbol:



We have labelled the inputs into the gate A and B, and the output X. There is one output from it.

When we make an expression from this, we can use . to represent the AND gate. In this case the **logic statement** would be either expressed as:

X = A AND B *or* **X = A.B**

The logic of the AND gate is very simple. For the output X to be 1, both inputs either input A or input B is 0, output X will be 0.

We can represent this logic in the form of a **truth table**. This is a table that gate or circuit by listing all the possible values that can be used. A truth ta

Input		Output
A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

Reading the truth table

→ If A = 0 and B = 0 then X = 0

→ If A = 0 and B = 1 then X = 0

→ If A = 1 and B = 0 then X = 0

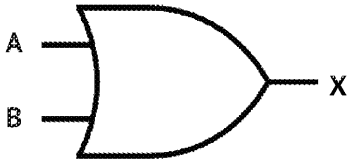
→ If A = 1 and B = 1 then X = 1

So we can see that the only way the output can be 1 from an AND gate is if that with two inputs there can be four possible outcomes.

In a truth table we can also use TRUE instead of 1 and FALSE instead of 0.

OR

The OR logic gate is represented by the symbol:



We have labelled the inputs into the gate A and B, and the output X. There is one output from it.

When we make an expression from this, we can use + to represent the OR gate would be expressed as:

X = A OR B *or* **X = A+B**

The logic of the OR gate is also very simple. For the output X to be 1, either to be 1. If both inputs are 0, then output X will be 0.

We can represent this logic in the form of a truth table. A truth table for ou

Input		Output
A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

Reading the truth table

→ If A = 0 and B = 0 then X = 0

→ If A = 0 and B = 1 then X = 1

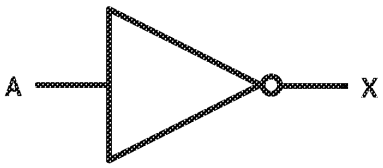
→ If A = 1 and B = 0 then X = 1

→ If A = 1 and B = 1 then X = 1

So we can see that if the input is 1 then the output from an OR gate will b inputs there can be four possible outcomes.

NOT

The NOT logic gate is represented by the symbol:



The NOT gate is a little different because it only has one input. We have la the output X.

When we make an expression from this, we can use *overline* to represent statement would be either expressed as:

X = NOT A *or* **X = $\overline{A}$**

The lo the NOT gate is arguably the simplest of all the gates. For the be 0.

We can represent this logic in the form of a truth table. A truth table for ou

Input	Output
A	X
0	1
1	0

Reading the truth table

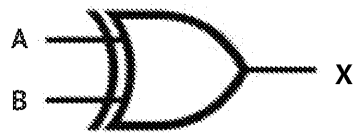
→ If A = 0 then X = 1

→ If A = 1 then X = 0

So we can see that whatever the input is into a NOT gate, the output will b with one input there can be two possible outcomes.

XOR (Exclusive OR)

The XOR logic gate is represented by the symbol:



We have labelled the inputs into the gate A and B, and the output X. There and one output.

When we make an expression from this, we can use $\oplus$ to represent the XOR statement would be either expressed as:

X = A XOR B *or* **X = A⊕B**

The logic of the XOR gate is also very simple. For the output X to be 1, eith If both inputs are 0, then output X will be 0 or if both inputs are 1, then the

We can represent this logic in the form of a truth table. A truth table for ou

Input		Output
A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

Reading the truth table

→ If A = 0 and B = 0 then X = 0

→ If A = 0 and B = 1 then X = 1

→ If A = 1 and B = 0 then X = 1

→ If A = 1 and B = 1 then X = 0

So we see that if either input is 1 then the output from an OR gate will be inputs there can be four possible outcomes.

How can we make more complicated hardware

AQA Specification Reference

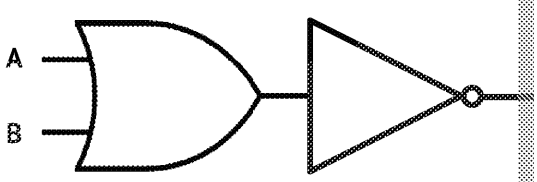
☑ Create, modify and interpret simple logic circuit diagrams.

Now we understand the logic of our three logic gates, we can begin to crea **logic circuit** (logic diagram). To do this we begin to combine our logic gate together to create our logic circuit. All operations that we perform on a computer use a logic circuit.

Let's take an expression and interpret it:

$$X = \overline{(A + B)}$$

We can see by looking at this statement that it has an OR gate that has two of this will go into a NOT gate and the output of the NOT gate will be look lik



We can also represent this as a truth table:

Input		Output
A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

Reading the truth table

→ If A = 0 and B = 0 then the OR output is

→ If A = 0 and B = 1 then the OR output is

→ If A = 1 and B = 0 then the OR output is

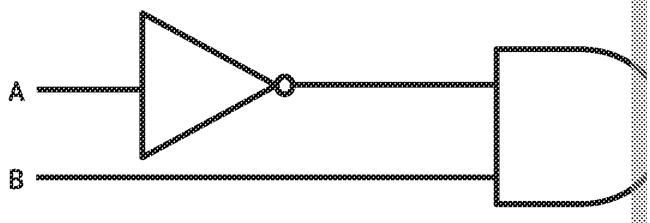
→ If A = 1 and B = 1 then the OR output is

This is how we can represent a logic statement as a logic circuit and a truth

Let's take another logic statement and interpret it:

$$X = \overline{A} \,.\, B$$

We can see by looking at this statement that it has two main outputs. Those AND gate, but output A will need to run through a NOT gate first. Therefore



We can also represent this as a truth table:

Input		Output
A	B	X
0	0	1
0	1	1
1	0	0
1	1	0

Reading the truth table

→ If A = 0 the NOT coverts it to 1 and if B

→ If A = 0 the NOT coverts it to 1 and if B

→ If A = 1 the NOT coverts it to 0 and if B

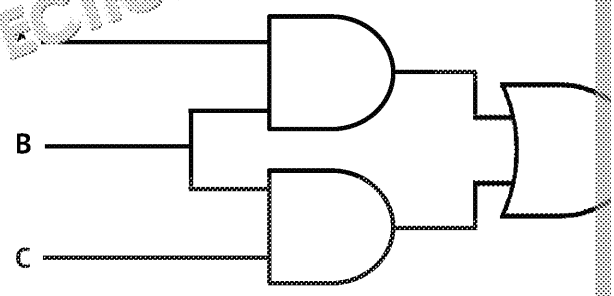
→ If A = 1 the NOT coverts it to 0 and if B

This is how we can represent a logic statement as a logic circuit and a truth

Let's take another, more complex logic statement and interpret it:

$$X = (A.B) + (B.C)$$

We can see by looking at this statement that it has three main inputs, A, B a good point for us to start. This is because it separates the two AND parts o will need two AND gates in our circuit of which the outputs flow into an OR gate that provides the output for X. One AND gate will need the inputs A a the inputs B and C. Therefore, our logic circuit will look like this:



The flow from input B needs to be split as it goes into both AND gates. Inp
gate, inputs B and C flow into the second AND gate and the two puts from t
gate. The output from this OR gate is X.

We can also represent this as a truth table. Our truth table will now need t
inputs. So that we can follow the logic of the circuit, we are going to also r
gates as well. We will name these D and E. Our tr le would be:

			Working outputs	
A	B	C	D	E
0	0	0	0	0
0	0	1	0	0
0	1	0	0	0
0	1	1	0	1
1	0	0	0	0
1	0	1	0	0
1	1	0	1	0
1	1	1	1	1

This truth table represents the logic statement X = (A AND B) OR (B AND C).
to make it easier to see what inputs are flowing into the OR gate. Working o
gate with the inputs A and B. Working output E is the output from the AND

If we take the first line of the truth table we can rea ke this:

If A = 0 and B = 0 then D = 0, If B = C an = 0 then E = 0, neither D

If we take the fourth line of the truth table we can read it like this:

If A = C = 1 then D = 0, If B = 1 and C = 1 then E = 1, If D = 0 a

What are the main hardware components in a c

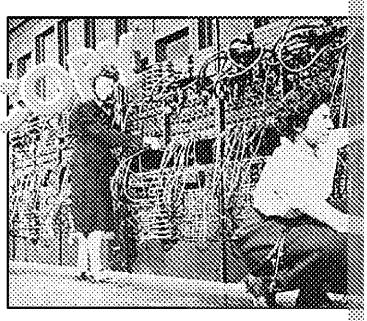
AQA Specification Reference

☑ Explain the role and operation of main memory and the following major c
unit: arithmetic logic unit, control unit, clock, register and bus within the V

A computer system is able to take in inputs, process them and output them
output is sometimes stored. It does this using a variety of hardware. A com
system is comprised of the **CPU**, **memory** and other components; for examp

The first electronic general-purpose computer system was the Electronic Numerical Integrator and Computer (ENIAC).

Creation began in 1943 and was ple ed in 1946. ENIAC was desig ed by John Mauchly and J Pres Ec the University of Pennsy ENIAC was able to solve large-scale nu ical problems and was used by the US Army as part of their logistics.



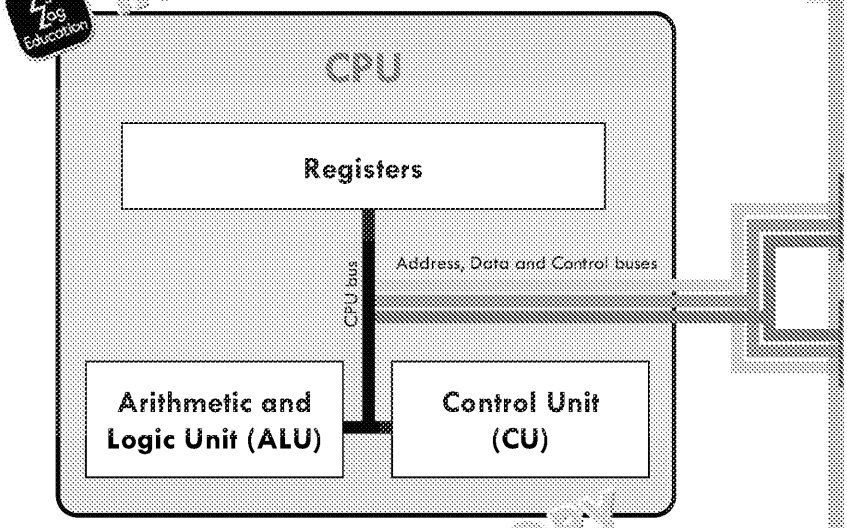
ENIAC: the first electronic general-purpos

Computer systems have developed immensely since the invention of ENIAC
now make them responsible for supporting many aspects of our daily lives.

CPU

The purpose of the CPU is to process data and instructions. It is where the decision-making takes place in the computer. Whatever you are using your computer for at any given time, be it playing computer games or doing your homework, the CPU is working tirelessly to allow you to do this. Data and instructions are transported around the CPU through the use of **buses**.

The CPU is made up of a number of component parts that you need to know. There is a particular CPU architecture that you need to focus on, which is known as the Von Neumann architecture.



A simple diagram of the Von Neumann architecture

Arithmetic and Logic Unit (ALU)

The ALU is the part of the CPU that carries out all the arithmetic and logical operations. Data is passed to the ALU to allow the required calculations to be carried out. The results of any calculations are then sent to be stored in a **register**.

Register – very small yet fast memory locations in the CPU, used to temporarily hold data and instructions during processing

Typically, the ALU includes a register that it uses to store intermediate results of calculations while the full calculation is being carried out. This register is known as the accumulator.

Accumulator (ACC)

The accumulator is built into the ALU; it is the register where the interim results of calculations are stored. It accumulates the results of the calculation, hence its name. If it did not have an accumulator, it would need to store the results of each stage of the calculation and then read it back in again to perform the next stage – making it a much slower process.

Control Unit (CU)

The control unit is responsible for directing the flow of all data inputs and outputs, the different stages of the fetching, decoding and execution of an instruction, and data through the different parts of the CPU. It also controls and monitors the hardware that tells each component in the CPU, the computer's memory and the hardware what to do. The CU communicates with the rest of the components by sending control signals.

Memory address register (MAR)

Each location within a computer's memory (RAM) has a memory address. Th address is used to locate the data or instruction that is stored there. The MA holds the address location of the next piece of data that is to be fetched int the CPU, or the address where a piece of data will be sent to be stored in R The address location is sent to and from the MAR using the address bus.

Memory data register (MDR)

The MDR holds the actual data that is being fetched into the CPU, or the da that is being sent to be stored in RAM. The data could be a value or it could an instruction. The data is sent to and from the MDR using the data bus.

Progr unter (PC)

The program counter is a register that holds the address of the next instruc designed to indicate where the CPU is up to in a program sequence. The pr the instruction pointer (IP) or the instruction address register (IAR). There i address of the current instruction that is being processed; this is called the

Cache

The cache is a small section of memory that is built into the CPU. It stores t instructions and data to allow quick and easy access to them. There are thre being progressively further away from the CPU.

- The first type of cache memory is L1 cache, typically operating at sp
- The second type is L2 cache, which is slightly slower and further aw
- Finally, L3 cache is the cache memory furthest away from the CPU,

You can think of the cache as a type of st ra e oard. The front of the c you would put here are the com n that you would use the most as them. The back of the oard is the L3 cache. The things you would put h would use the is because it would take the longest amount of tim

In orde ocess an instruction, the CPU carries out a process called the f

Clock

The clock located inside of your computer is different to the clocks that we computer refers to an electronic oscillator circuit that takes advantange of electric signal with a precise frequency. This frequency can be used to time made by the CPU.

Clock speed (the frequncy of the clock) is typically measured in GHz, where second. As of 2021, the fastest recorded CPU clock speed was 8.722 GHz (A generated it required liquid nitrogen cooling to remain functional!

Bus

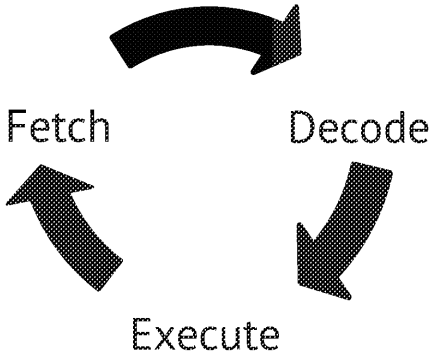
Data and instructions have to be moved aro en the CPU, memory series of buses. There are internal h at move data and instructions b an external bus working wit pe ipheral devices.

How does the CPU perform operations?

AQA Specification Reference

☑ Understand and explain the fetch–execute cycle.

The fetch–execute cycle is the process a CPU goes through in order to proc
the fetch–execute cycle, both the data and the instruction are loaded into t
are ready to be processed. It is the computer's operating system that loads



Once a cycle is complete, the CPU is ready to carry out the next

What does an instruction look like?

The instructions that are processed by the computer come in a specific form
binary bits. This is another agreed-upon protocol; when the computer receiv
an instruction it will always know what to do, and where to find the things it
needs. The actual instruction itself is split into two parts, the **opcode** and the
operand. The opcode tells the CPU what is to be done, and the operand tells
CPU what to do it.

opcode	operand
ADD	21

We can use a set of commands called mnemonics to create computer progra
correspond to the ADD command, with the operand telling the CPU which m

Fetching an instruction

The first step the CPU carries out is to fetch the instruction and data into th
to indicate the address of the instruction that is to be carried out. This valu
address register so that the instruction or data stored there can be located.
memory to locate the address.

Decoding an instruction

In order to process an instruction, the CPU needs to understand the instruct
an instruction. In order to decode an instruction, the CPU uses an instructio
that are written in machine language that the CPU understands.

Executing an instruction

This is the part of the cycle where any actions required by the instruction ta
that need to be carried out using the data. The ALU may be used at this sta

How can the performance of a CPU be affected?

AQA Specification Reference

☑ Explain the effect of the following on CPU performance: clock speed, proc

The performance of a computer can be dependent on the performance of th of the CPU we mean how quickly it can carry out instructions. There are th performance of a CPU; these are the clock spe cache size, and the nu

Clock speed

The speed at which the C can carry out instructions is called the clock sp cycles per seco refers to one cycle of the fetch–execute cycle. Clo one cy second would be 1 hertz. A typical CPU could have a clock sp This me it is capable of carrying out two billion cycles per second – tha the clock speed of the CPU, the more instructions it can process in a second it can process, the greater the performance of the CPU.

Number of processor cores

The number of cores a CPU has can vary. If a CPU has a single core it is cap processing one instruction at a time. If a CPU has two cores, referred to as it can process two instructions simultaneously. This effectively doubles the of instructions it is capable of processing in a second.

A single-core 2 GHz processor can process two billion instructions per seco a 2 GHz dual-core processor can process four billion instructions per second dual-core or quad-core processors; and as of 2020 octa-core processors are example both the Playstation 5 and Xbox Series X processes have 8 cores. T computer requires a great deal more power than to run a single-core proces

Cache Size

The cache is the a the CPU where the most commonly used instructio quick y access to these instructions. If a CPU has a larger cache, it c instruct and data and has a greater range of them available for quicker range available, this can increase the performance of the CPU for the more

Discussion point: Since 1971 the number of transistors in a CPU has roug affecting the performance of the CPU. This is called Moore's Law. This is think this might have happened? *Hint: more computers have started to use*

Why does a computer need memory and storag

AQA Specification Reference

☑ Understand the differences between main memory and secondary storage

There are two types of memory found in the CPU. These are random-acces memory (**RAM**) and read-only m ry (ROM). Without memory we would n able to run programs. Th dif from secondary storage – where data is it can the be lo d into the RAM when necessary.

Second rage refers to any storage – either internal or external to a co – that is not under the direct control of the CPU. An example of internal se storage would be the **hard disk**; an example of external storage (often refer as offline storage) would be a CD or an external hard drive. We need this fo permanently storing data ready to reuse, share and distrubute.

There are three types of secondary storage – optical, magnetic and solid st
control of the CPU is called primary storage. An example of this would be t

What are RAM and ROM used for and how are t

AQA Specification Reference

- ☑ Understand the differences between RAM and RO
- ☑ Understand why secondary storage is required.

Random Access Memory (RAM)

RAM is a location in a computer where all the programs and data that are currently in use are stored. These are stored in RAM when they are in use as this allows the computer to quickly access them. This is because RAM is quicker to read to and write from than any other storage in a computer, such as the **hard disk**.

RAM is very useful as it allows quick access to the data and programs in use; however, the items in RAM only stay there as long as the computer is turned on. As soon as the computer is turned off, all the data and programs this means that RAM is an example of what we call volatile memory. In ord we want to use again, a computer needs a hard disk to save these items to. disk they will not be lost when we shut our computer down.

RAM is given this name as any location in the memory can be directly acces move sequentially through each memory location to find the data or progra memory location through the use of a highly optimised and efficient system

Read-only Memory (ROM)

It is called read-only memory because the computer only reads from this m and does not write to it. ROM contains the programs that allow your comput 'boot up' and the data and programs that are stored in ROM are not lost when computer is turned off; they will still remain in the ROM.

ROM is often described as non-volatile memory, meaning it is permanent. ROM remain permanently in the memory, even when the computer loses po

RAM vs ROM

The differences between RAM and ROM are described below:

RAM	
• Stores programs and data in currently in use • Can be written to and read from • Volatile • Larger in memory capacity • Contents lost when computer turned off	• Stores the pro computer • Can only be re • Non-volatile • Smaller in me • Contents not l

What are the different types of secondary stora

AQA Specification Reference

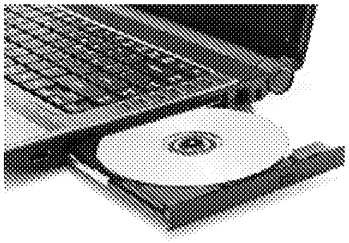
- ☑ Be aware of different types of secondary storage (solid state, optical and n
- ☑ Explain the operation of solid state, optical and magnetic storage.
- ☑ Discuss the advantages and disadvantages of solid state, optical and magn

Magnetic storage

Magnetic storage devices use m[illegible]ets t[illegible]ecord data on rotating metal pla
An example of a magn[illegible]ge is a hard disk drive.

The ad[illegible]es and disadvantages of magnetic storage include:

Advantages	
• Large storage capacity • Fast access to read and write data • Fairly inexpensive to manufacture	• Data can be lo mechanical pr • Can suffer wea



Optical storage

Optical storage uses a lens and a light bea
disk. Examples of optical storage are CD, D
size. CDs typically can hold up to 700 MB
4.7 GB of data and Blu-rays can hold up to

The advantages and disadvantages of opti

Advantages	
• Disks are [illegible] light making them v[illegible]ta[illegible]e • Di[illegible]re cheap to manufacture • Disks are fairly durable, meaning that they are safe to store data on for long periods of time • Some formats, such as CD-R and DVD-R, mean that data cannot be overwritten	• The storage ca compared to o • In some cases required to rea

Solid-state storage

Solid-state storage uses flash memories to store data. This works by using
electrical circuits to store the data. Examples of solid-state storage are soli
state drives, SD cards and USB memory sticks.

The advantages and disadvantages of magnetic st[illegible]e include:

Advantages	
• Faster boot-up s[illegible] not need to 'warm up' du[illegible]ha[illegible]moving parts • C[illegible]made to be very compact in size • Large storage capacity • More robust than magnetic due to having no moving parts	• Expensive to m • Have a limited written to and can be thousa

Choosing a suitable storage device

There are a number of elements that we may want to consider when choos
data; these are:

Capacity	The amount of data we can store on the device
Speed	The rate at which we can transfer d
Portability	Whether we need to mo e t ie around and carry it wit
Durability	The length o th evice will safety store data for wit
Reliability	Wh t ta is stored without any technical errors, and th
Cost	he cost of manufacture for a device

Example 1 – Software Company

*A software company would like to give away a free trial of its latest software
well-known technology magazine. The company needs to choose a suitable s
device to distribute its free trial. The company will need to consider a device
portable as it will need to be attached to the magazines; they will need to ch
device that is cheap to manufacture as it will need a large quantity of them to
in each magazine. They will also need to choose a device that will keep the d
reliable. They are not likely to need a device that has a large capacity as the f
trial software will be reasonably small.*

Discussion point: What would be the most suitable storage device for th

Example 2 – Model Car Compan

A model car company w to make a new remote-control car. They wa t a u to be able to input programs into the mod at will give it instructions on how to drive around certa ks.

*The user will make use of a keypad on the base of the car to do this. The inst
device in the car when input.*

Discussion point: What would be the most suitable storage device for th

How does cloud storage work?

AQA Specification Reference

- ☑ Explain the term 'cloud storage'.
- ☑ Explain the advantages and disadvantages of st rage when compare

The cloud is an ever-growing fea t e Internet. More and more businesses and in i ials are choosing to use it every day.

Cloud e i name given to the remote storage of data and softwa we access using a device. The data and software that we want to use are not stored on our individual device or hardware, but stored in a remote location, normally by another company. We use the Internet to access the data and software whenever we need it. The servers in the remote location use either magnetic or solid state storage.

The advantages and disadvantages of using the cloud include:

Advantages	
• Users do not need to purchase additional hardware to store data and software • Companies do not need to employ technical staff that may be needed to maintain the hardware to store the data and the software • Companies and individuals do not need to worry about running a backup of their data when it is stored in a cloud • It is easy to access files and software from anywhere in the world as long as we have an Internet connection	• We ar… anoth… as we… • If we d… or hav… to acc… • If the… able t… made…

Discussion point: How private do you think information is in the cloud? In … cloud can be accessed by the US Government – do you think this is the ca…

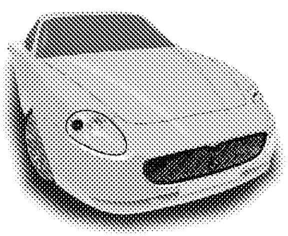
What is an embedded computer system?

AQA Specification Reference

☑ Understand the term 'embedded system' and explain how they differ from …

An embedded computer system is normally built into a piece of machinery o… 'embedded'. It is a computer system that is designed to provide very limite… functions. It mostly consists of a small microprocessor that provides a simil… input, processes it and provides an output as a result.

An embedded computer system does not look like a normal general-purpos… keyboard, a mouse or a monitor. Embedded computer systems are built into… daily life such as a washing machine, a smoke detector or air conditionin… industries, for example medicine, in electronic devices such as blood pressu…



Embedded computer systems can also be found i… 50 embedded computers each performing a diffe…

Discussion point: What embedded systems can …

Manufacturers use embedded systems in their devices for a number of reaso…

- They allow the device to be programmed to automatically perform one or a small number of functions.
- They can reduce the size of the machinery or device. If a larger processor performing more functions is used, it would mean the device would need to be larger in size to accommodate this.
- They can reduce the cost of the machinery or device. If a larger pro… used, most of the functionality would be wasted as only a small num… Therefore, by removing this wastage, the cost of manufacture can b…

Discussion point: Is a smartphone an embedded system?

Chapter Summary

Software

- There are two main types of software that are used on computer syste applications software.
- Systems software controls the operations of hard e in a computer sy provides a platform to run applications s va
- Applications software is the ev programs we use to create docu with each other using t
- An operatin software that is loaded by the computer after th o ns e hardware in a computer system and manages all othe op g system through a user interface.
- The operating system performs a number of functions including memo peripheral management, user management and file management.
- Utility software is a type of systems software. It helps manage, maint resources. There are a number of different types, including encryption data compression and methods of backups.
- We can write programs in a high-level language or low-level language languages as they are closer to human language. Low-level languages understands.
- Programming languages need different types of translators known as a compliers.

Logic Gates and Circuits

- A logic gate is a basic foundation block of a digi al circuit; it controls th digital circuit.
- The logic of an AND ga e is: For the output to be 1, both inputs need to output will be
- The logic of an OR gate is: For the output to be 1, either input needs to ou ill be 0.
- The logic of an XOR gate is: For the output to be 1, either input needs t output will be 0. If both inputs are 1, the output will be 1.
- The logic of a NOT gate is: For the output to be 1, the input must be 0.
- Logic gates can be combined together to create a logic circuit diagram
- Logic gates and logic diagrams can be represented as a truth table. Th of the gate or the circuit. We can also write expressions.

Hardware

- The purpose of the CPU is to process instructions given to a computer instructions and any data that requires storage as a esult is stored in th
- The CPU has a number of components th are involved in carrying out
- The fetch–execute cycle is the gi to one whole cycle of proce
- The clock speed of a CP is measured in hertz. One hertz is the equiva greater the nu of hertz available, the greater the performance of t
- A co processor can process one cycle at a time. A dual-core p si eously. The more cores a CPU has, the more cycles it can proc the performance of the CPU.
- The cache is a small part of the CPU where commonly used instruction commonly used instructions and data that can be stored, the quicker th greater the performance.

- RAM is the place in a computer where all the programs and data that a
  volatile memory.
- ROM contains the programs that allow your computer to 'boot up'. It i
- Flash memory is a type of non-volatile memory that is used to store da
- Secondary storage is any storage, either internal or external to a compu
  control of the CPU. There are three types: optical, magnetic and solid-s
- There are several factors a user will need to consider when choosing a
  include capacity, speed, portability, durability, reliability and cost.

Exam-style Questions

1. Memory management is one of the main functions of an operating syst
   Explain how the operating system manages a computer's memory.

2. State three other functions of an operating system.

3. In a sentence, explain the logic of an OR gate.

4. Draw a logic circuit to represent the logic statement: X = A AND (NOT B

5. Janey has the following spec for her computer:
   - 2 GHz single-core proces
   - 4 GB RAM
   - 500 GB HD

   Describe two ways Janey could upgrade the performance of her compu

6. Explain how the CPU processes an instruction.

7. Explain the difference between RAM and ROM.

8. A company is developing a camera drone as a product. They need to c
   storage for all the footage the camera will record.
   Explain which storage type would be most suitable and why.

9. Explain the difference between a high-level language and a low-level l

10. What is the difference between an interpreter, compiler and assembler

Chapter 5: Computer Networ

In this chapter you will learn:

- What is meant by a computer network.
- The different types of network (PAN, LAN and WAN).
- The different ways of connecting a network, specifically the star and bus t
- Different methods that allow us to commu[illegible]er a network.
- Methods of securing networks.
- How communication is achieved over the Internet.

Wha[illegible]a network?

AQA Specification References

- ☑ Define what a computer network is.
- ☑ Discuss the benefits and risks of computer networks.

Up until the 1990s, most computers in both the home and in businesses were **stand-alone computers**. A stand-alone computer is one that is not connected to any other computers that it needs for regular use. When we connect computers together we create a **network**.

One of the first networks to be created was back in 1969. This became known as the Advanced Research Projects Agency Network (ARPANET). Universities decided to connect their computers together so they could communicat[illegible]h each other and share resources. This netwo[illegible]k was the predecessor to the Internet.

We network ou
we can commu

We still use networks primarily for these two functions, to be able to share files and resources and to be able to commu[illegible]with each other.

There are a range of advantages and disadvantages of networking compute

Advantages	
• Users can share files and resources with others. • Users can access their files and resources from another computer on the same network. • Servers can be created to centrally control a number of operations and services on a network, such as security and file backup. • Communications can be sent to any computer on the network. • **Peripherals** can be shared.	• Networks can b unauthorised a • Malware and v computer to c control and er • Depending on element of it f issues for the • A high amount network to run

Discussion point: Do you think that the widespread use of comp[illegible]tworks has changed the way we communicate with each other for better or worse?

Per
com

Net
trav

What are the different types of computer netwo

AQA Specification References

- ☑ Describe the main types of computer network including Personal Area Net Local Area Networks (LAN) and Wide Area Networks (WAN)
- ☑ Explain the following common network topologies: star, bus.

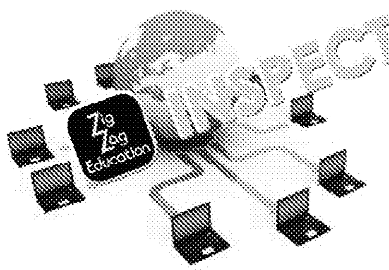
There are different ways in which networks can be structured and this will d purpose. It will also depend on the resources available to create the netwo

Local area network (LAN)

A LAN is a network that covers a small geographical area. They are normally contained within a single building or a small site of buildings. LANs are normally found in the home, schools and small businesses.

The key characteristics of a LAN include:

Characteristic	Description
Connection method	Can be copper cables, coaxial cables, twisted cables,
Ownership	The structure is normally owned by the individual or
Transfer rate	High – often as much as 1 Gb per second (gigabits, n
Transmission errors	Fewer errors as packets of data are being sent over a
Security	Can be kept fairly high as security can be controlled an



Wide area network (WAN)

A WAN is a network that covers a large g cover a city, several branches of an orga countries. The Internet is the largest WA often a collection of connected LANs.

The key characteristics of a WAN include

Characteristic	Description
Connection method	Can be coaxial cables, twisted cables, fibre optic ca also make use of telephone network systems, lease satellite communications.
Ownership	Parts of the structure will often be owned by other
Transfer rate	Normally restricted to less than 200 Mb per second
Transmission errors	Greater chance of an error occurring as packets of dat
Security	Can be difficult to manage due to the high number

Personal area network (PAN)

A PAN is a network that is limited to a single person. Unlike a LAN or a WAN, a personal area network only has a reach of a couple of metres. A PAN can be used for file transferral between devices, sharing Internet between devices (tethering) and printing using NFC.

An example of a protocol used in PANs is Bluetooth.

Characteristic	Description
Connection method	Wirelessly or wired, depends on the hardware used wirelessly, or you may be transferring music onto a
Ownership	Owner is the user of the network.
Transfer rate	Depends on the technology being used; Bluetooth per second, whereas USB 3.0 can handle up to 5 gig
Transmission errors	Less prone to errors as packets of data are being se
Security	Easy to manage as the network is limited in size, to that interact with each other.

What are the different ways in which a network

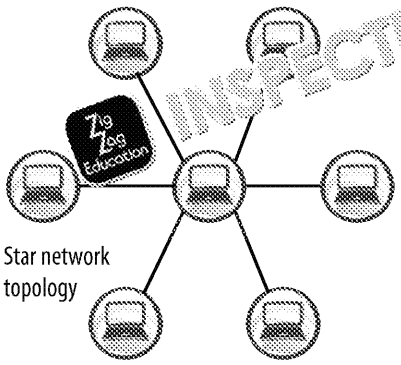
AQA Specification Reference

☑ Explain the following common network topologies: star, bus.

A **network topology** is essentially the structure of a network. It is the way in which all the computers and devices are connected together. You need kno structure and features of two network topologies; these are the star and the topologies.

Star topology

In a star network topology there is a central computer or server that all oth to. Each computer is also indirectly connected to every other computer via



Star network topology

If a computer fails in the star topology it computers, unless it is the server in whi security of a star topology is generally computer goes through the central com with another computer. **Data collisions** depending on the structure of a network. This is not too much of a problem on a star network, though, as each computer has its own dedicated cable that connects it to the server.

However, this network structure can be expensive to set up as it needs a cer amount of cabling to connect each computer.

Bus topology

In a bus topology there is one central backbone of cable that each and every computer on the network is connected to. At each end of the central cable is a *terminator*, which stops data being continually being moved around the network.

One advantage of this network is that it is cheap; once the central cable is insta adding computers to it is incredibly easy as the majority of the cabling already exists (unlike star networks where each device needs its own cabling). If a portion of the cabling fails, the bus network will be divid devices on each side of the network would be unable to communicate – wh computers that need Internet access are no longer on the same network as

To send data around the network, data is sent in both directions around the network is sent the data, but only to check that it is the intended recipient. central bus are in place to stop data from being sent back in the other direc between data that is being sent directly after it. The central cable limits th send data at once – in fact, only one computer can send data at once, to pr disadvantage, bus networks are only suitable for small networks – as the m network, the slower the rate of transmission.

Did you know?!

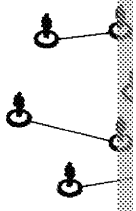
Normally networks use a mixture of topologies, depending on the purpose of a In this example, the network has a hybrid topology.

How are network devices physically connected?

AQA Specification References

- ☑ Understand that networks can be wired or wireless.
- ☑ Discuss the advantages and disadvantages of wireless networks as oppose
- ☑ Explain the purpose and use of the network protocols Ethernet, Wi-Fi.

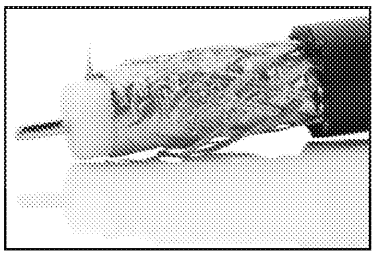
In order to create a physical network, we need certain hardware. There are some fundamental hardware devices that are required to create most networks. The most basic of these is the transmission media to form a wired net



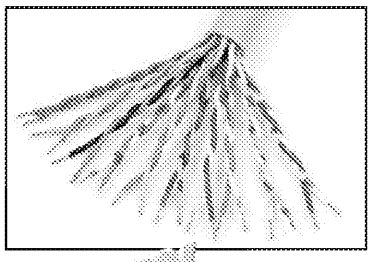
Wired networks

The transmission media is what will be used to carry the data around the network, specifically the cables. There are several different types of cables that can be used; these include:

- Coaxial cable
- Twisted pair cable
- Fibre-optic cable



Coaxial cable



Twisted pair cable

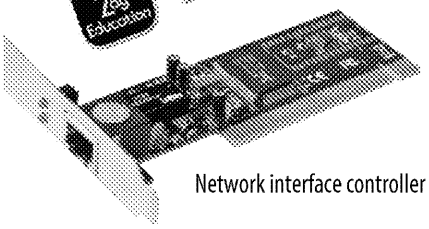
Coaxial cable is a type of cable that has a central wire that is surrounded by an insulating layer. Many coaxial cables then have a final outer layer that acts like a jacket. This type of cable is mostly used in Ethernet.

Twisted pair cable is a type of cable that has two separately insulated wires that are twisted around each other inside an outer layer. This is the most common type of cable that is used in a network.

One of the largest problems wired networks face is **interference**. Also know
from background radiation and other electrical devices. Along the cable, da
from the other electrical sources cause bits to flip. This is what causes erro
this problem we can add check bits that can tell us if an error has occurred.

Did you know?!

*Error-correcting codes fall into a field of comp[illegible] sc[illegible]ce (and mathematics)
aim is to be able to detect and corre[illegible]ny errors as possible in what has
that as messages get longer and l[illegible] the chance that there has been an err
need to be sent al[illegible] the message!*



Network interface controller

As well as transmission media, a com
connecting the transmission media to
transmitted around the network. The
called a network interface controller,
that is installed into a computer to all

Wireless networks

Alternatively, a wireless network can be created (although there is nothing
a network from having devices connected through wires and wirelessly). A
connected wirelessly is there is no physical connection between the device
network. This can be seen in most modern laptops – they tend to have a p
hardware called a wireless network interface controller (WNIC) that works i
same way as an NIC, except using wireless signal[illegible]ead of transmission m

In order for computers to connect w[illegible]y to a network, the network will
(WAP). A WAP is a networ[illegible]ard[illegible]e device that allows any device that has
network. In many h[illegible]n[illegible]works the WAP is built into the router. In the in
antenn[illegible]e w[illegible]eless access point.

Wi-Fi is the name given to the wireless technology that we use to connect a
Unlike a hardwired connection, Wi-Fi uses radio waves to provide a connect
are transmitted by a WAP that normally has a wired connection to the Inter
capability will detect the radio waves and allow a connection to the networ

The radio waves of Wi-Fi are mainly in two different **frequency** bands:

- 2.4 GHz – ultra-high frequency
- 5 GHz – super-high frequency

The frequency of the band represents the number of radio waves per secon
frequency band is separated into a number of different channels. A device
the radio waves. If two devices close together are u[illegible]g channels that are c
interference. Therefore, it is possible for a u[illegible]er to choose the channel used

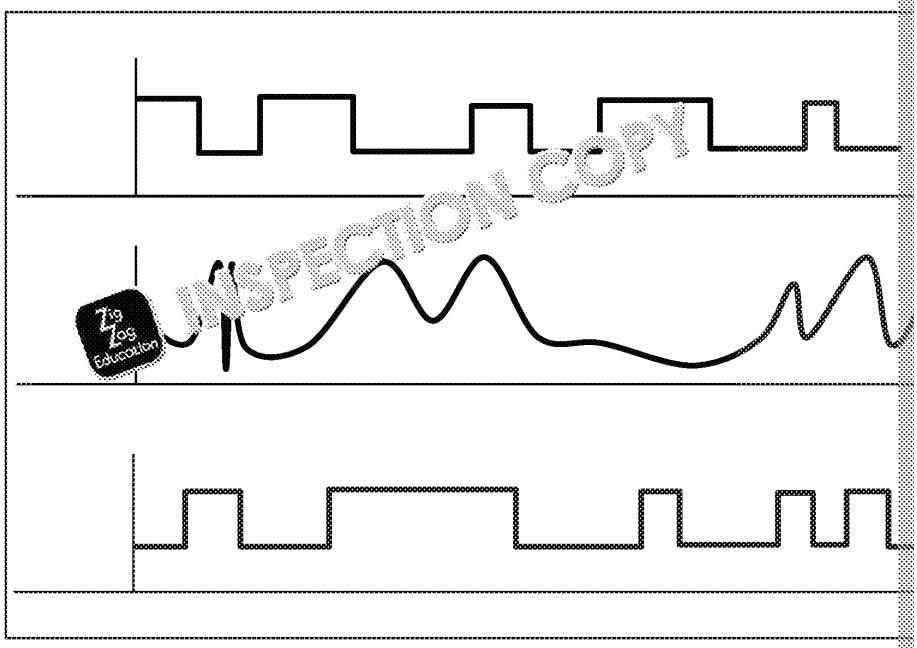
Encryption – scrambling data to make it unreadable if intercepted during transmission

[illegible]portant when using a wireless netwo
[illegible]place. A username and password adds one
network, but a wireless encryption method

Most W[illegible]will have three methods of encryption to choose from: wired eq
Wi-Fi protected access (WPA) and WPA2.6+89.

Discussion point: To what extent do you think we should trust encryption
For example, WEP listed above is not used as often, as it is easily crackabl

Wireless networks also face interference issues. Sometimes wireless netwo
such as microwaves, as they also emit signals at a similar frequency.



Wired vs wireless

There are multiple pros and cons for using one type over another.

	Advantages	
Wired	• Connections are generally faster and more th[illegible] wireless networks • [illegible] to manage the security of the network	• The nee[illegible] impracti[illegible] avoid be[illegible] • Limited [illegible] connecti[illegible] • Can only [illegible] that spe[illegible] • Transmis[illegible] dependi[illegible]
Wireless	• Can connect to networks from different geographical locations • No limit on the number of physical connections • Files can be transferred between devices more conveniently using wireless networks; e.g. sending a photo from your phone to a computer.	• Data tra[illegible] and less[illegible] distance • Wireless [illegible] be more[illegible]

Why should our networks be secured?

AQA Specification Reference

- ☑ Understand the need for, and importance of, network security.
- ☑ Explain the following methods of network security: authentication, encryp

Both types of network (wired and wireless) are susceptible to cyber-attacks network or gaining unauthorised access. If a malicious/unauthorised attacker manag network, the results could be fatal for potentially companies that store data.

To prevent these attacks from occurring, great care should be made to ensu are multiple methods for securing a network; some of the most popular meth

Authentication

To help prevent unauthorised access to a network, users must be encouraged to set strong passwords. A strong password is one that:

- Is more than a few characters in length (usually more than eight)
- Uses a combination of letters, numbers and symbols
- Uses a combination of lower-case and capital letters
- Is not identifiable data that is easily linked to the user, for example a birthday, pet name

A strong password will be much harder to crack and is far less likely to be g brute-force attack. Many organisations will set rules for their users' passwo password is chosen. They often force their users change their password pe

Discussion point: How well do you think your passwords would stand up they would be discovered? Does it you change how you set password

In addition to these measures, many companies require two-factor authenti to a user. One example of 2FA involves asking the user for their password, requiring them to enter it into a physical device that then returns a code th This authentication is better than just using passwords, as if a thief manage they do not have the physical device to verify themselves. Alternatively the require the user verifying their identity by clicking on a link in an email.

Encryption

When we store data on a network it is always going to be at risk. We need everything we can to protect this data, and one of the things that we can d **encrypt** the data that we store. This way, even if a hacker gains access to t it will not be of much use to them as they will not be able to read it.

Encryption – scrambling data to make it unreadable so do to security in transmitting the data. The re decrypt the scrambled data to re al data.

To make it we can en that we st

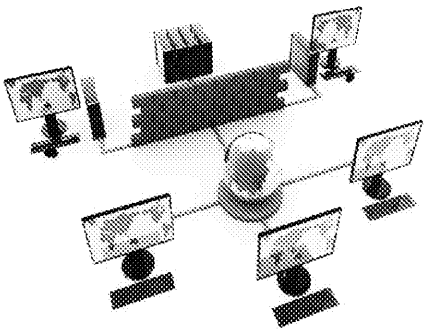
A very (and insecure) method of encryption is using the Caesar ciph each le ixed number of places. Consider the following key:

Plaintext	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Ciphertext	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B

The text '**I LOVE COMPUTER SCIENCE**' would be encrypted as '**U XAHQ OAY**

Note: This type of encryption should never be used in a practical applicat
analysis can break this encryption incredibly easily, as certain letters appe
language than others. We can also simply test each of the 25 possibilities

Discussion point: With a friend, create your own secret code similar
See how hard it is to



Firewall

A firewall is a network security systen
that can either be hardware or softwa
based. It uses sets of rules to control
network traffic coming into and going
out of a network. All traffic that is
allowed into and out of the network i
traffic that is unauthorised is rejected
network, or is not allowed to leave th
out in a firewall policy are designed t
deny it access.

MAC address filtering

Each network card in a computer is given a unique hardware value called a
address. These values are assigned by the manufacturer of the hardware de
range given to them by the IEEE (Institute of Electrical and Electronics Engi

To prevent unauthorised access to a network, there is the option to use MA
devices that have an NIC with specific MAC address can join the network (o
addresses can be refused access).

Did you know?!

*MAC address filtering is no longer recommended as MAC addresses can easily b
trick the network into thinking your device has a specific MAC address (one that
as the address has been spoofed, you get instant access to the network.*

What is a protocol?

AQA Specification Reference

- ☑ Define the term 'network protocol'
- ☑ Explain the purpose and use of common network protocols: TCP, UDP, IP,

In order for us to use the Internet to communicate effectively using a netwo
need to put in place a number of **protocols**. These are rules that govern h
network functions and how communication is carried out. If protocols did n
exist it would be like a group of people trying to communicate with each ot
in a different language. This would make the process very difficult! A proto
to effectively be speaking the same language when communicating with ea

Different protocols are used for different purposes. The main networking p

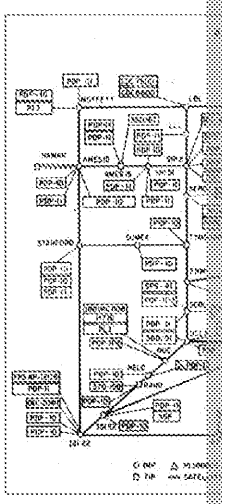
Protocol	Applicat
TCP/IP *Transmission Control Protocol / Internet Protocol*	This sets rules for how devices on a netw manages the separation of a file into data network. It then ma ges the process of IP part giv ac acket and address to a
UDP *User Datagram Protocol*	T ocol is an alternative to the Tran used over TCP when speed is a priority – protocol that sends datagrams with no gu
HTTP *Hypertext Transfer Protocol*	This is used by web browsers to access w communicate with a web server.
HTTPS *Hypertext Transfer Protocol Secure*	This is a more secure version of HTTP. It and data as it is sent using this protocol. shopping sites to keep personal data sec
FTP *File Transfer Protocol*	Used in conjunction with TCP/IP to transm
POP *Post Office Protocol*	The POP3 protocol is used to retrieve em receives a user's emails and they are the the user or the user's email client checks and downloads any mail using the POP3 downloaded, it is th deleted from the s
IMAP *Internet Message Access Protoc*	IMAP v or s i very similar way to POP t ie ail is not deleted from the server v until the user chooses to delete it.
SMTP *Simple ansfer Protocol*	POP3 and IMAP are concerned with the d but SMTP governs the sending of emails
Wi-Fi	Wi-Fi is not a single protocol, but actuall communications standardised by IEEE. T prefix 802.11, where the first protocol w most recent is 802.11ac. The first Wi-Fi supported wireless transfer speeds of 11 recent protocols can theoretically reach 500x faster)!
Ethernet	Similar to Wi-Fi, Ethernet is an IEEE stan (beginning with 802.3) regarding the tra networks. The wire an either be coppe are norma se or linking your router at y can access the Internet.

How is information sent over the Internet?

AQA Specification Reference

☑ Describe the four-layer TCP/IP model.

A protocol is normally separated into layers, with each layer responsible for different parts of the process. The process is broken down into layers to make it less complex. The main things that need to be considered when using a network to communicate data are:
What is it that is being communicated? Who is the data being sent to? How will the data get there?



Logic map of ARPANET, t

The original networking model was created by DARPA, used on the first proper network known as ARPANET (Advanced Research Projects Agency Network) in 1969 – originally designed for military application. Little did they know that eventually people could access a network thousands of times larger than this from devices as small as your mobile phone!

The protocol that we (and ARPANET did) use for communication over the In

The protocols found in TCP/IP manage the separation of data into packets a address for its destination. The TCP/IP protocol has four layers, shown belo

The Application Layer

This layer is concerned with collecting and distributing data. It m a suitable form for transmission. The application layer is the la that users of network are operated. This includes email clients an

The Transport Layer

This layer is concerned with establishing and terminating connect on a network. It does this via the use of a router. This layer also detection and correction functions, and establishes the speed at be sent and received.

The Network Layer

This layer allows the exchange of data between lots of differen layer that the IP part of the protocol is used to establish a route the data packet.

Data Link Layer

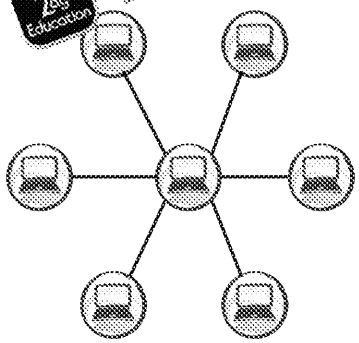
This is concerned with the transmission media that is used to send d network. It ensures the network hardware can be used to transmit transmission media can be used.

Chapter Summary

- A network is a collection of devices that are connected together.
- We mainly use networks to communicate and share resources.
- A network can be a PAN, a LAN or a WAN. A PAN is a network limited t
  LAN is a network that covers a [illegible] geographic area, and a WAN is a n
  geographic area.
- A network topology is the way in which the network is wired and struct
  n[illegible] topologies are star and bus.
- Wi-Fi is the wireless technology that we use to connect devices to the
  provide the connection.
- There are a number of measures that can be taken to protect a networ
  firewalls, and MAC address filtering.
- A protocol is a set of rules that govern how a network operates. Differ
  applications; they are also made up of a number of different layers.
- The TCP/IP model is the main set of protocols that are used for commu

Exam-style Questions

1. Explain two benefits of networking computers [illegible]ether.
2. Explain the difference betw[illegible] a LAN and a WAN.
3. What is the t[illegible]y of the network shown in the diagram below?



4. State two disadvantages of using a bus network.
5. Describe when data collision occ[illegible]n a network.
6. Identify and de[illegible] methods of securing a network.
7. D[illegible] the operation of two different layers in the TCP/IP protocol.

Chapter 6: Cybersecurity

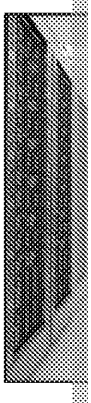
In this chapter you will learn:

- That information systems need security measures in place to protect th
- That there are multiple kinds of threat that can affect system security, involve stereotypically 'hacking'.
- Methods to detect and prevent cyber security threats.

What forms of cyber threats can a network be s

AQA Specification References

- ☑ Be able to define the term 'cybersecurity' and be able to describe the main
- ☑ Understand and be able to explain the following threats: social engineerin and default passwords, misconfigured access rights, removable media, unp



Networks provide many benefits, but they also come with a great number of risks. Many people recognise the security precautions they need to take with their physical belongings, but they do not exercise as much care with their security when it comes to using networks. This type of security is often given the name 'cybersecurity'.

A network can come under attack in many different forms, and criminals are always inventing new methods of attack to overcome the increased security that is developed to prevent the attacks.

Listening to communications is one common method of data interception. important to use when sending confidential information over the Int website uses HTTP for their transaction processing you should probabl

More often than not, an attack is performed by targeting the people who us itself. After all, why try to hack a system when you could just try to trick a People are usually the weakest link in a system!

Other attacks come from software that you have voluntarily downloaded. A computer – some can encrypt all of your files and then threaten to delete t watch you enter your passwords so they can send them back to the creator

We need to realise the value of information and put in place as able to, in order to prevent it b extremely difficult, as threats p developing and it is a constant defend against this.

Cybercriminals recognise the v spend much of their time devis really see its value?

What is social engineering and how can we prot

AQA Specification References

- ☑ Define the term 'social engineering'.
- ☑ Describe what social engineering is and how it can be protected against.
- ☑ Explain the following forms of social engineering: blagging, phishing, pha

Social engineering preys on the issue that people are often the weak point i the security of a network. It preys on the problem that people can often be influenced into aiding access to a network, often without them even knowi or realising it is happening.

This is part of human nature; we often want to believe someone's story an involves giving your password away we probably should be more wary!

There are four methods of social engineering that we will look at:

- blagging
- phishing
- shouldering

Blagging

An example of social engineering is **blagging** (sometimes known as *pretexti* an employee in a company presenting themselves as a network administrat will often act as if the employee has reported a problem with their compute is that they have reported. Many employees probably haven't reported an is is confused, then just forget about the call. They may fall upon one employ issue and will then seek to obtain details from them such as their login and them to fix the problem. The employee may then give the details and the p password to access the system.

> **Blagging** – the art of convincing someone that you are someone else to make them directly give away information such as passwords

To combat blagging you should always b who is actually speaking on the phone. the phone number will be external from – in which case you should report the n actual network administrator.

Another particularly nasty scam is getting a phone call saying that you have but to claim it you must transfer a certain amount of money into a holding that the prize can be 'released'. In this case you need to think, if you did no competition, then it is most likely to be a scam!

> **Discussion Point:** The 'Band Name' game involves finding out what you c adjoining the name of the street you first lived on and the name of your f why might you not want to play this game with someone you don't trust?

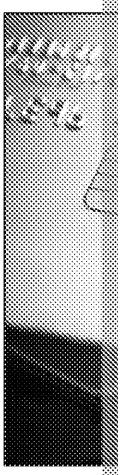
Phishing

Another form of social engineering is called **phishing**. Phishing is when an unauthorised person tries to collect personal and sensitive data by disguising themselves as a reputable individual or organisation. The kind of data that phishing emails are looking to obtain is passwords and bank details. The perpetrator will send some kind of communication, such as an email, to the victim, pretending to be from a bank, or a website that requires a username password.

The email will be designed to look legitimate and will normally contain to click to follow. The email will normally advise them that there is someth have, or that they need to verify a matter with an account they have. They this. The link will take them to a replica webs organisation they are presenting themselves t their personal details. The personal details w commit **fraud**.

Fraud is the crime in which you purposefully deceive someone for monetary gain

We should be aware of any email or communication that we get that states that the sender is from a legitimate organisation. Most organisations will not ask you to provide your personal details in this way over web communications, so we should be very wary of any organisation that does. If we look closely at an email, we can often tell when it is 'phishing' for our data:



Criminals us

- There will sometimes be spelling errors or bad grammar in the email. If the writing style is not professional, formal and grammatically correct, this can be an indication it is fake.
- The email is impersonal. Many phishing emails are sent out in bulk. This means they are not always addressed to an individual; for example, 'Dear Customer' and not 'Dear John'.
- The email will often want you to urgently respond to something and be some kind of detrimental effect, such as account closure or a fee
- When you click on the sender's email you will see that it is not actu actually from a spam email.

Below shows an example phishing email:

Subject: You have received a secure message from Bank of America
From: admin@thebankofameria.com
Date: April 26, 2016

You have received a secure message from Bank Of Amerrica

Read your secure message by opening the attachment, securedoc.htm to open (view) the file or save (download) it to your computer. For b then open it.

If yo concerns about the validity of this message, please contac

First time users - will need to register after opening the attachment.
Help - **hxxs://securemail.thebnkofamerica.com/websafe/help?topi**

Discussion Point: Discuss the reasons why this email should be treated w

Shouldering

The final social engineering technique is **shouldering** (sometimes known as *shoulder surfing*). Shouldering is where the perpetrator obtains information while watching you use the device they want access to. They may learn your password by simply watching you enter it. This is why on card readers the number pads are often shielded to stop any prying eyes from learning your PIN code.

Shouldering – spying on people to get their usernames, passwords or other

What threats exists in downloaded software?

AQA Specification References

- ☑ Describe what malware is and how it can be protected against.
- ☑ Describe the following forms of malware: computer virus, Trojan, spyware

Malware is short for malicious software, and this is what it is, software designed to cause malice to a person's computer system. It is designed to disrupt or damage the computer system and the data that it holds. Malware is an all-encompassing term for a number of threats; including:

Malware	Description
Virus	This is a computer program that infiltrates a computer system and is intended to cause damage to the computer system by corrupting files, deleting available memory causing it to crash.
Trojan horse	This is a type of malware that is disguised as a harmless file. If the seemingly harmless file is downloaded, the malware is downloaded, it can carry out the attack it was designed to do.
Spyware	These are computer programs that gather data about people's actions. This records the key presser from a user on a computer. It may be possible to pick out personal and sensitive data, such as passwords.

We must be very careful when we choose to download a file from an email or a website. Most malware is disguised as a Trojan horse. It may look like an innocent application, file or game, but it could unleash a great deal of harm to your computer and files.

If we are not certain that the download is from a reputable source, we should question whether it is safe to be downloading the file at all.

What other threats exist?

There are other ways that your data and computer systems can be put at risk. These include:

- Phishing
- Weak passwords
- Misconfigured access rights
- Removable storage media
- Unpatched/outdated software

Pharming

Pharming is where even though an email is legitimate, when you click on th link you get redirected to an illegitimate website. This can be done by mod certain files on your computer, or hacking the domain name server that is re for that web address (the server that links what you have written, e.g. *www.* to an IP address, e.g. *32.11.16.4*).

The website that you get sent to will often be an exact replica of the normal w some message appears stating that you cannot log in right now and you shou attack is still completely unaware that is going on – they will just assume tha

Weak passwords

It is important that when you set passwords, you think about how *strong* the the less likely they are to guess. So passwords such as password, abc123 a easy to guess. In order to protect systems, it is important that you think ab including text, numbers, upper case, lower case and even symbols.

It is also important to change passwords regularly. A default password is o register. Most organisations get you to change the password straight away change the password, this is an easy one to guess.

Discussion Point: Which of these passwords is more secure: **elaine123** or Can you make it any more secure?

Misconfigured access rights

When a user is added to a network, they are usually assigned specific **access** the IT/network manager. These accounts will determine which network the user has access to, the file permissions they have (in terms of being abl modify and delete files) as well as the control they have over system settings. Th access a user is given will depend on the users' position or role in the

When access rights are misconfigured, you could end up giving people acce For example, think about your school. What could happen if you suddenly

Removable storage media

Removable media refers to external storage devices such as USB flash drive with removal storage media is their ability to transfer malware such as viru reason, many organisations forbid the use of removal storage media as part

Another risk is that are easily misplaced – and if intercepted, the data can b many cases in the news where flash drives have been found containing hig

Research Point: Find some examples of security b es caused by loss

Unpatched/outdated softw

All software has bugs and security loopholes, especially when it is first rele all softw up carried out regularly on your computers. It is even organi Software updates contain the security patches for the looph as softw becomes old and new software versions are developed, the pat encouraged to update the software. If you do not do this, your software ca

Research Point: Find some examples of cyber security attacks that have b outdated software.

How can we prevent cybersecurity attacks?

AQA Specification Reference

- ☑ Explain what penetration testing is and what it is used for.
- ☑ Understand and be able to explain the following security measures: biome CAPTCHA, using email confirmations to confirm a user's identity, automati

There are two main methods of trying to pre cybersecurity attacks. The the current system and fix them. This is called 'penetration testing' (or pen system may have no vulnera however, this does not mean that the case a certain numb security measures can be put in place to prevent n

Pene testing

In order find out whether there are any security vulnerabilities in a netwo company can employ a team of people to simulate potential attacks on their This is called **penetration testing** (or *pen testing*). Penetration testing can be out manually by individuals, who carry out attacks and reveal any security w It can also be carried out by automated software that will perform a series o

People who carry out penetration testing are often referred to as ethical hackers, or white-hat hackers. Once a vulnerability has been identified, the organisation can look to develop its network security and make sure that th attack can be prevented. There are two types of penetration testing; the fir is called *white-box* testing and assumes knowledge of the internals of the system. This testing simulates an attack from someone with detailed inside knowledge of the system.

Now, this is not always the case, and this is where the other type of testing called *black-box* testing, is carried out. The aim of black-box testing is to simulate a full-on cyber ... attack – these attacks often assume knowledge of th ... and might involve attacking a system through floo than t... handle. This type of attack is called a *denial of service attack*

In both cases, any vulnerabilities that have been found are reported back to

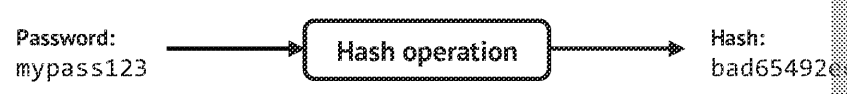
Biometric measures

One method of locking down a system is to use **biometric se** most popular form of biometric scanning is *fingerprint scann* phones. The purpose of this measure is to lock down the sy information that is unique to the owner of the device. Finge scanning measures have not always been perfect; in 2006, a science programme beat a fingerprint scanner using a printo fingerprint and a small amount of saliva!

Password systems

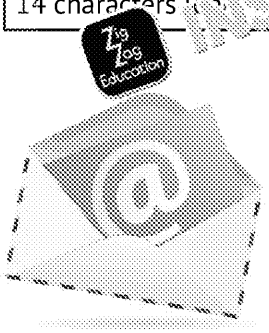
One of the common methods of securing a ne vo is to password protect eve engineering would hopefully convi ... at this on its own is not complete weakest link in an inform ... system. For more security, another authenticati two-factor autha ... (to add an extra layer of confidence that the correct

Compa ... so have a responsibility to ensure that their password systems 'no-nos' of password systems is to store passwords in plain text on a systen of the passwords, which can be found by performing a mathematical operat



The idea is that this operation should not be reversible – so if the password passwords getting leaked, it is the jumbled hashes that get leaked instead. hash, you need to guess every possible password until there is a match! This password, and is why you should have long passwords and use different sym passwords can be checked a second, the amount of time it takes to brute-fo

	a–z	A–Z, a–z
7 characters long	8 seconds	17 minutes
10 characters long	[illegible]	40000 hours
14 characters long	17 million hours	293 billion hours



Email confirmations

Email confirmations are used to ensure that a perso website is using a valid email address. This is usua mass signing up to a website and putting unnecess servers. It is often the case that limited data is sto verify their account, in order to save on storage spa

CAPTCHA

An alternative method to verifying that someone signed up to a website is using a **CAPTCHA** system.

CAPTCHA stands for:

Completely Automated Public Turing test to tell Computers and Humans Apart

and exists to stop people from creating bots that automatically sign up to a to the user and is asked to input the phrase (or word) into a text box. handw[illegible] to exist, the idea is that the phrase has been distorted past the the case above, a line through the text along with some subtle rotation has the computer.

Automatic software updates

Penetration testing can be incredibly efficient, but comes at a large cost to company. An alternative to pen testing is to ensure that **automatic software updates** are turned on (which is free!). This method will still fix vulnerabili in each individual piece of software, but not as quickly as pen testing.

General methods of protecting your data

The key idea is to be sensible and careful when putting personal data on th Internet it can be very hard to take it off without leaving any data left behin account on a website, there is a high chance that the organisation will have backups.

In general, if you are downloading something from the Internet you should respect your PC. Trying to download a game from *httpx://www.superfree* good idea the time, but it is probably more sensible to download it from

With emails, you should ensure that you have a suitable spam filter and onl sources. While most email clients ask whether you really want to open a fil *definitely_not_a_virus.jpg.exe*, you might accidentally click 'yes' and end up a

Chapter Summary

- A network can create risks as well as bring about benefits.
- Social engineering preys on the issue that people are often the weak p
  It preys on the problem that people can often be influenced into aidin
  them even knowing or realising it is happening.
- Phishing is when an unauthorised person tries to collect personal and
  themselves as a reputable individual or organisation.
- Pharming is when your computer has been affected in a way that chan
  to fraudulent websites, even though the address is correct.
- Shoulder surfing is where access is gained to your account after the attacke
  password/PIN.
- Malware is harmful software that is unknowingly downloaded onto a u
  designed to disrupt or damage the computer.
- Viruses are self replicating programs that are intended to slow down th
  usage.
- Trojans are programs that appear normal, but contain malware that ins
  using the valid program.
- Spyware is a type of malware that reports your computer usage to the
  to steal your passwords.
- Adware is a type of malware that displays adverts on your computer so
  money for getting people to look at adverts.
- Penetration testing is where 'white-hat' hackers find vunerabilites in so
  to the company that own the software.
- Biometric measures can be used to lock a device to a specific person, u
  to them – such as fingerprints or iris imaging (located in the eye).
- CAPTCHA and email verification can be used to stop robots from signin

Exam-style Questions

1. A company wants to make sure that its system is very secure. It hires a
   testing to improve its network security. Explain what is meant by pene

2. Describe two other security methods that the company could put in pla

3. Describe the purpose of CAPTCHA.

4. James received an email advising him his social media account has bee
   click a link and confirm his details to remove the attack on his account.
   State the name given to this type of email.

5. Explain two ways in which people can be the weak point in the securit

6. Describe why using only a password system is not sensible. Identify ho
   made more secure.

7. State one reason why a company might use automatic software update

Chapter 7: Relational Databa
Structured Query Language (

In this chapter you will learn:

- About the concepts of relational databases
- How to use SQL to retrieve, insert, edit and [illegible] data in a relational data

What is a relati[illegible] database?

AQA S[illegible]ca[illegible] References

- ☑ Ex[illegible]e concept of a database.
- ☑ Explain the concept of a relational database.

A database is a structured and organised way of storing data. All of the dat be sorted in different orders and interrogated to provide information. There

Flat file databases have all the data in one big table. The table below is an

PetOwner Table

OwnerName	Address	PetName	PetType
Susie	3 High Street	Dotty	Dog
Harold	67 Main Road	Bob	Goldfish
Harold	65 Main Road	Chirp	Budgie
Kazim	5 Mill Road	Harley	Dog
Aleesha	9 High Street	[illegible]ard	Cat
Oskar	81 [illegible]an	Arthur	Dog
Osker	[illegible]Mile Lane	Mob	Cat
Susie	3 High Street	Gabby	Dog

For the amount of data, this is fine, but if you can imagine a vet practice wi this would not be manageable. You will see in the data above, there are pr

- We have inconsistent data, where some people have differences. T people moving and not all of the records being updated. This make
- We also have data redundancy. This is where we have repeated dat

Discussion point: Can you find the inconsistent data and redundant data i

To fix the problems caused by flat file databases, we can use relational data different tables the data that goes together and th[illegible]s relationships bet example, we would have a Pet table and an Ow[illegible]Table.

Owner Table

OwnerID	[illegible]ame	Address
001	Susie	3 High Street
002	Harold	67 Main Road
003	Kazim	5 Mill Road
004	Aleesha	9 High Street
005	Oskar	81 Mile Lane

Pet Table

PetID	PetName	PetType	Microchipped	OwnerID
D01	Dotty	Dog	Yes	001
F01	Bob	Goldfish	No	002
B01	Chirp	Budgie	No	002
D02	Harley	Dog	Yes	003
C01	Pilchard	Cat	Yes	004
D03	Arthur	Dog	No	005
C02	Mob	Cat	No	005
D04	Gabby	Dog	Yes	001

What are the concepts of a database?

AQA Specification Reference

☑ Understand database concepts

There a number of different concepts that are important to know when look

Concept	Definition
Table	This is all the data about one entity
Record	A set of data about one item in the database. For exam
Field	A characteristic of what the database is storing. For ex
Primary Key	This is a field that uniquely identifies a record. It allow with the same name to be uniquely recorded.
Foreign Key	When two tables are related, the primary key in the par table to form the relationship and link them together.

So, how do these relate to the database we have been using? Well the who a table.

Primary Key

Field

PetID	PetName	PetType	Microchipped	OwnerID
D01	Dotty	Dog	Yes	001
F01	Bob	Goldfish	No	002
B01	Chirp	Budgie	No	002
D02	Harley	Dog	Yes	003
C01	Pilchard	Cat	Yes	004
D03	Arthur	Dog	No	005
C02	Mob	Cat	No	005
D04	Gabby	Dog	Yes	001

So how does SQL work?

AQA Specification References

- ☑ Be able to use SQL to retrieve data from a relational database
- ☑ Be able to use SQL to insert data from a relational database
- ☑ Be able to use SQL to edit and delete data in a database

We are now going to look at how we use SQL with a database. To do this w

Owner Table

OwnerID	Owner Name	Address
001	Sue	3 High Street
002	Harold	67 Main Road
003	Kazim	5 Mill Road
004	Aleesha	9 High Street
005	Oskar	81 Mile Lane

Pet Table

PetID	PetName	PetType	Microchipped	OwnerID
D01	Dotty	Dog	Yes	001
F01	Bob	Goldfish	No	002
B01	Chirp	Budgie	No	002
D02	Harley	Dog	Yes	003
C01	Pilchard	Cat	Yes	004
D03	Arthur	Dog	No	005
C02	Mob	Cat	No	005
D04	Gabby	Dog	Yes	001

Select

Selecting data is where we retrieve (search for) data that meets certain con
find the details of all the dogs we would use the command:

```
SELECT *
FROM Pet
WHERE PetType = 'Dog'
ORDER BY PetName ASC
```

The asteri

ORDER BY
ascending

Another example might be if we need to select the owner name and pet nam

```
Select Owner.OwnerName, Pet.PetName
FROM Owner, Pet
Where Pet.Microchipped = 'No'
ORDER BY OwnerName DESC
```

The
the
num

Insert

We may want to insert a new pet for an owner:

```
INSERT INTO Pet(PetID, PetName, PetType, Microchip
VALUES ('D05', 'Tony', 'Dog', 'Yes', 001)
```

Update

So what would happen if Mob the cat gets a Microchip? Well the record wo

```
UPDATE Pet
SET Microchipped = 'Yes'
Where PetID = 'C02'
```

Delete

There may be a reason to delete a record, for example if the owner changes
To delete the dog with another from the database, the SQL would be as fo

```
DELETE from Pet
WHERE PetID = 'D03'
```

Chapter Summary

- Databases are a way of storing data in an organised fashion.
- We can have flat file databases, but these result in redundant and inco relational databases.
- Relational databases are made up of tables, consisting of fields, record
- We use a variety of SQL commands to retrieve, insert, update and dele

Exam-style Questions

A youth club keeps a database of the young people who attend. Here is par to store member data. The table is called Member.

Member Table

MemberID	FirstName	LastName	Telephone	Age
AB123	Mustafa	Saddique	07745678345	17
BC234	Alicia	Thomas	07793849283	18
CD345	Paulo	Rodrigues	07483729183	17
DE456	Alana	Smith	07829321345	18
EF567	Diana	Fernandes	07783747876	18

1. What is the difference between a primary and foreign key?
2. Look at the table. Which field would you use as the primary key?
3. How many fields and how many records are there in the table?
4. Explain 2 advantages of using a relational database rather than a flat fi
5. Write an SQL statement that finds the first and last names of all the 17
6. Alana has turned 19 and is leaving the youth club. Write an SQL state

Chapter 8: Consequences of Technology on Society

In this chapter you will learn:

- How the way that we interact with computers is dict d by law
- The impact that digital technology has on the en onment

What is the im t of digital technology on the

AQA S ca n Reference

☑ Ex e current ethical, legal and environmental impacts and risks of d

Many people blindly use technology without considering the effect that it h of phones are thrown away every year yet materials are chosen for cost, rat communications and internet history is monitored by ISP's and government software is downloaded illegally all over the world causing companies to m even going out of business.

Note: In order to be aware of the various issues that appear in Computer S we are up to date with our knowledge and understanding of current issues Therefore, it is very important for us to regularly read news stories surroun awareness. If we do this, it will give us a good basis of knowledge to draw allowing us to develop our own opinions that will help us answer the essa

There are four main issues that need to b c nsidered in this chapter – Eth environmental issues and iss c rning our privacy.

How is ou acy affected by digital technolog

Many p ut very personal information on the Internet, mostly using th However, it is very difficult to keep data private on the Internet. Social net people to post personal details about their life. A lot of data about a perso from these posts. Many of these sites will have a privacy policy that is agre account. Most users, however, do not read the privacy policy and have no i that they post. This makes them very unaware of what they have agreed to

Discussion point: Think about the last social networking account that you privacy agreement? Do you know what the company can do with any of t

A company may have a privacy policy that gives them the right to:

- Sell your personal data
- Make any of your photographs and d tai public
- Disclose your Internet s o a buying habits to allow for targete
- Retain any of y a posted, including images and videos, even a un

As long y stay within the limits of the privacy agreement you have sig and more.

Many social networking sites allow a user to set the level of privacy on acce opened, these settings are often quite relaxed and open, so it is always adv and change them to the level you would like as soon as you open the accou

A criminal could also monitor a person's online activity and social media, a
more information the person posts, the greater the understanding of their i
that can be developed. This would make it easier for the criminal to steal t
identity.

There are other privacy issues we need to consider that can arise through th
technology. We are watched a great deal by surveill cameras on a daily
when we walking into shops, banks and othe pl e n the high street, eve
we are simply walking down the hig . This kind of technology is beco
more and more sophistic and has been vital in identifying many crimina

Facial it ware can be used alongside surveillance cameras to t
possib ect's movements throughout a city, so that the police can wat
every move. However, some people argue that this is an invasion of privacy
that the police and the government authorities should not have this much p
track a person's movements. They see it as an invasion of their privacy.

Discussion point: Do you think this kind of technology should be used to c
or do you think it is a step too far?

What do we mean by ethics?

Ethics are an agreed set of principles that people should try to follow to keep conduct. While they do not have to be followed, it is normally in everyone's best intere o do.

When we talk about ethics, we a g to the things that people think are right and wrong in society. It is different to legislation that legally dictates what is right and wrong. Ethics represents society's opinio t what is right and what is wrong. When we talk about ethics in Computer Science, we are considering what society's opinions are about the use of computers and the development of hardware and software.

One major area that is subject to lots of ethical reviews is the topic of artifi
should we try to make a computer think for itself?

Another example is: *should our search history be accessible by advertisement*

Discussion point: What do you think about the development of artificial i
about companies keeping track of your search history?

What laws are there relating to the use of digita

Unfortunately, despite the many benefits that technology brings, it can also cause a great number of issues. Society has reacted to many of these issues by creating **legislation** that governs the use of technology, and puts in place **sanctions** if rules are broken.

The Data Protection Act (2018)

The Data Protection Act was originally passed in 1998 and was updated in 2018. The updated version was released to incorporate the principles of another legislation called the General Data Protection Regulation (GDPR). It also passed in 2018.

The Data Protection Act governs the personal data held by an organisation. from their customers and potential customers. This data is very valuable. T amount of data an organisation is allowed to collect about a person. It is d organisations from holding or using inaccurate information about an indivi the data when it has been collected.

The Data Protection Act has eight main principles that an organisation is re

1. Personal data shall be processed fairly and lawfully
2. Personal data shall only be obtained for a lawful purpose and not u the one it was obtained for
3. Personal data shall be adequate, relevant and not excessive for the
4. Personal data shall be accurate and kept up to date
5. Personal data shall not be kept for longer than the purpose it is req
6. Personal data shall be processed in accordance with an individual's
7. Personal data shall be kept safe and secure at all times, and protect destruction
8. Personal data shall not be transferred to a country outside the Euro country has adequate levels of protection in place

The aim of the Data Protection Act is to:

- Make sure that data is securely transferred between companies and
- Prevent a person or an organisation from storing or using inaccurat private life or business
- Give the public confidence that businesses are regulated for the use
- Allow an individual to check, and request destruction of, the inform an organisation
- Place accountability on organisations to demonstrate that they are store and transfer

Discussion point: What impact did the update of the Data Protection Act in

An individual has a number of rights under the Data Protection Act; these in

- They are allowed to see what data is being held of theirs by an orga individual to write to the organisation to request to see they data th allowed to charge a small processing fee to provide the data. The o requested data within a reasonable timescale.
- They are allowed to have any data that is incorrect or out of date be
- They are entitled to compensation if they can prove that an organis breaking the principles of the act. Damage can be physical or finan

There are some exceptions to the Data Protection Act. An organisation do reques affects national security, if they believe it would cause exces

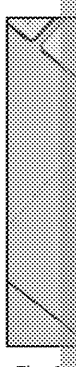
Sanctions: Serious breaches of the Data Protection Act can carry a fine of up deliberately and maliciously breached, then a prison sentence can be given

Discussion point: What kind of national security issues or excessive harm think may not be disclosed? Do you think that it is right that these can be

Computer Misuse Act 1990

The Computer Misuse Act protects personal data held by organisations from hackers. The act makes the following illegal:

- Unauthorised access to computer material – this refers to entering a computer system without permission
- Unauthorised access to computer materials with intent to commit a further crime – this refers to entering a computer system to steal data or destroy a device or network
- Unauthorised modification of data – this refers to modifying or deleting data, and also covers the introduction of malware onto a computer



The C

There is one major issue with the Computer Misuse Act: intent has to be pro prosecuted and if intent cannot be proven, a perpetrator can claim access w be proven there needs to be a witness to the crime being planned and to th to hack into the system. This is often a very difficult thing to obtain.

Sanctions: Minor breaches of the act will result in a heavy fine or a six-mon of the act can carry a 10-year prison sentence.

Discussion point: Do you think it is right that in must be proven to be the Computer Misuse Act?

Copyright, Designs and Patents Act 1988

The Copyright, Designs and Patents Act protects **intellectual property**. This refers to anything an individual or organisation has created, including books, music, films, games and software. It makes it illegal to:

- Share any work that has copyright without the owner's permission
- Plagiarise the work of another that has a copyright

The Internet made it much easier for people to commit these illegal acts of piracy, making it much easier to steal the intellectual property of another and share their files.

Sanctions – breaking the act can result in a heavy fine or a prison sentence of up to two years.

Discussion point: Many people share files illegally using file-sharing netw... running the website should be prosecuted for enabling this to occur? This ... of individuals under the Copyright, Designs and Patents Act.

Whare are the legal and ethical considerations

Proprietary software

In most cases when you buy software from a company, you are not purchasing it – instead you are buying a licence that allows you to use the software. The type of software is called **proprietary software.** In this type of software, only the **compiled code** is released.

The advantages and disadvantages of proprietary software include:

Advantages	
• The software will have undergone thorough and rigorous testing to rid it of any bugs and discover any security issues • The software will have full customer support and warranty options that come with it • Updates to improve features in the software will be released periodically • The interface of the software will have gone through an extensive design process in order to make it user-friendly	• The ... purc... they ... that ... • A us... to m...

Popular examples of proprietary software are:

- Microsoft Office – document creation software
- Adobe Photoshop – image editing software
- Garageband – audio editing softwar...
- Interne...
- Windows...

If you want to be able to access the source code, **open-source** software should be used. This software is free, and is open for anyone to modify to cater to ...

Source code – the programming commands that are compiled into an executable program

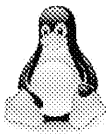
Open-source software is a type of software for which the **source code** is made freely available. T... free of charge and some users will look to develo... to it. If these features are successful after testing ... them. This gives users the freedom to adapt the ...

Open-source software

The advantages and disadvantages of open-source software include:

Advantages	D
• Usually free of charge • Can be adapted to suit a user's needs • Community that encourages development and use of the software; they are normally happy to help any users • Many contributors to development of the software result in creative features being added	• The software may n susceptible to bugs There is no official warranty with the s • User interface may software; developm • Developing the soft and not every user

Popular examples of open-source software are:



- Open Office – document creation software
- Mozilla Firefox – web browser
- GIMP – image editing software
- Linux – operation system

Creative Commons Licencing

Creative Commons is an organisation that provides licences to individuals o organisations that want to give the public the ability to legally share and de work. If a person's intellectual property has a Creative Commons Licence, t does not need to ask the owner's permission to do this.

There are normally conditions to what can be done with the work; dependi of Creative Commons Licence that is applied:

Type of Licence	Condition
Attribution	This allows work to be shared, copied and modified,
Share-alike	This allows work to be shared, copied and modified, and the modified work must be released under the s
Non-commercial	This allows work to be shared, copied and modified, and the work cannot be used to make a profit
No derivative works	This allows work to be shared and redistributed, but

Digital Right Management (DRM)

To get around digital rights management (**DRM**), some people '**crack**' softwa the Copyright, Designs and Patents Act 1988

However some people argue that digital right management often hurts the user, and doesn't stop people from illegally downloading and using the software. Certain DRM requires a user to be always online, even if the prog should only need an internet connection. DRM also tends to stop one person from legally buying software and then transferring it between other people. This is usually by linking hardware to software activation.

What issues are there relating to wearable technology?

Technology that we can wear on our person is called 'wearable technology'. This type of technology is common in the field of health and fitness in particular, where devices are used for monitoring and tracking data such as location as well as more personal data such as heart-rate. Even in fashion, there exists clothing that is embedded with LEDs or fibre-optic cables that can glow in different patterns.

Wearable devices that record information or store data immediately face ethical issues regarding the wearer and people around the wearer. In particular, with the rise of micro cameras can be made incredibly small, to the point where you would not realise they can be placed on devices and then can record people without them knowing.

One example of wearable technology put under the spotlight in 2013 was Google Glass, a projector that fits onto a pair of glasses and allows the user to perform actions such as taking a picture without having to take their phone out of their pocket. Immediately there were concerns about the ethics of using such, as conversations can be covertly recorded, and pictures can be taken without permission. Questions regarding their use to commit crime were also raised. Google Glass was banned for use in cinemas to stop people recording films, preventing potential copyright infringement.

What issues are there relating to computer-based implants?

RFID (Radio-Frequency IDentification) chips are just one example of a **computer-based implant** used on pets in case they get lost, and store the owner's address or phone number on the chip. Some think that these kinds of devices could be used on humans.

Swedish company Biohax International is one such organisation, who were tasked with embedding radio frequency identification (RFID) chips into the hands of their hi-tech workers, allowing them to access their building by pressing their hand against a sensor. Of course this was entirely optional and the worker was asked before receiving the rice-grain-sized implant. *Why do you think that people may be willing to do this?*

RFID – technology usually used to track animals and objects

Computer-based implant – technology that is physically located on someone, under their skin

One concern regarding this technology is the security of the RFID chip. People could essentially steal someone's identity by stealing their chip. There should be some form of encryption on the chip, especially if it is used to identify a person. An example of this being done poorly was in 2013, when Taiwan's national ID chip was discovered to have incredibly insecure encryption.

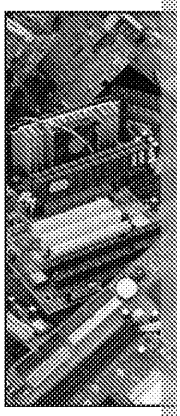
What issues are there relating to wireless networks?

Unsecured wireless networks can raise certain ethical issues – *because a network is unsecured, does that mean you should use it?*

There is a practice known as 'wardriving', where you drive around using hardware to find unsecured networks. *Is this ethical?* In 2010, Google came under fire when it was revealed that their Street View cars had been collecting personal and unencrypted data from unsecured wireless networks. Some of this data included medical information – *surely this is not OK without the permission of the owner?*

While no laws were broken, as this data was 'publicly available', some wondered whether it was ok to do it in the first place!

What is the environmental impact of technolog



Vast amounts of un

Our increased use of technology has a great impact on the environment. When we use the plethora of electronic devices we possess, we use a lot of energy. The more powerful the devices we use, the more energy we also use. The vast majority of the energy that we create is non-renewable. We have an ever-depleting [illegible] resources for this kind of fuel and [illegible] the resources often causes pollution to the environment. In order to make the new devices we crave we need to use a great deal of resources, such as plastics and precious metals. Again, extracting and creating these resources can cause pollution to the environment.

We have developed a constant need for the newest and best device. This is and also drives the technology market to produce even more. This causes u technology that we have, in favour of getting the newest device. These thr disposed of and there is the danger that much of it can end up in landfill. T waste from some of the metals used can leak into the soil.

There are ways that we can help protect our environment by being more ca

- Don't leave our electronic devices switched on constantly, or even
- Recycle the old technologies we no longer want or need.
- Carefully consider whether we need a new devic or whether the o deals with our needs effectively.

Discussion point: Companies [illegible] sending many of our discarded less economically [illegible] countries. Do you think this practice is ethi

Wha[illegible]mpact does digital technology have on h

With the advent of machine learning and artificial intelligence, computers h 'think' and act accordingly to different situations. This has raised concerns specifically in the military and the defence industry. There are ethical guid that use computers, specifically that they should be controlled by humans.

Robots such as drones are also regularly criticised for the lack of respect to to be out of reach for consumers, quadcopters with cameras are becoming i price comes down, but they can be used to spy on people and gain access t Some areas have employed drone-catching drones to stop them from being film sets, military bases and airports!

Driverless cars: who is accountable when technology fails?

[illegible]ut[illegible]omous vehicles (also k *cars*) have been in developm undoubtedly both exciting a issues surrounding them.

In 2018, a pedestrian in Ariz Uber vehicle failed to detect The question of why the car investigated thoroughly, and safety. However, a very seri *accountable when the techno*

Chapter Summary

- The use of computers can affect many areas of our lives, including our environment.
- Ethics represents society's opinions about what is right and what is wrong. In Computer Science, we are concerned with what society's opinions are about the development of hardware and software.
- Proprietary software is software for which only the compiled code is released.
- Open-source software is a type of software for which the source code is released.
- There are a number of legislative acts that govern the use of computers, including the Data Protection Act 2018, Computer Misuse Act 1990 and the Copyright Designs and Patents Act 1988.
- Many different areas in computer science need some consideration on their impact on society.

Exam-style Questions

1. State two reasons why a company include might include DRM with their software.
2. Describe two privacy concerns about wearable technology that can record data.
3. Explain what is meant by Creative Commons licensing.
4. Give one reason why weaponised robots should only work if they are controlled physically with the machine.
5. Explain two disadvantages of using social media.
6. We increasingly throw away technology in favour of the next new device. Discuss the impact this has on our environment.

Exam Tips

Below are examination tips that will be useful for your exams. They are d
you in the right direction for a few key aspects. I hope that these prove us

- One of the first things I recommend you look at is the list of comma
be used in the AQA examinations. There is a *command words* guide a
Every command word (such as *Identify*, *Describe*, *Discuss*, etc.) is expl
how to answer a question that uses that particular command word.

  When readi[illegible] exam questions, highlight or underline the comma
  Th[illegible] help your brain decipher what knowledge it is required for y
  req[illegible]d to do this.

- Look at the mark allocation for the question. This, along with the co
how many points you will need to make in your answer, and how in-

- There will be at least one written communication question on the pa
very carefully about the context you are given, and how you apply th
context. One way of doing this is to find technology news stories on
into the four key areas. Make sure in the exam that you plan your an
sure that you cover the four key areas.

- When drawing logic diagrams in an exam, make sure that you draw
clearly. If the examiner cannot decipher which logic gate you have d
award the marks. A common error is missing off the small circle at t
advisable to plan your logic diagram out before you write it in your e
have to cross it out if you realise you have got part of it wrong.

- When answering [illegible]e programming questions, decompose each probl
so[illegible] One way you can decompose the problem is by identifying
put[illegible] the program, any outputs that will need to come from the p
need to be carried out and any data that will need to be stored. You
plan the program.

- AQA have released a pseudocode guide on their website. You will n
pseudocode in this guide as any algorithms written in the exam will
You are not required to provide your answers in the given pseudoco
structure for us to do this.

- In the Paper 1 examination, the questions will indicate the type of r
be told for example, whether to draw a flowchart, write pseudo-cod
language that your teacher has registered you on.

- When writing program code, you will need to write code using all th
Make sure you give variables meaningful names (identifiers), use sui
indentation and [illegible]ments to improve the legibility of your code.

Answers

Chapter 1: Algorithms

1. One mark for:
   - Breaking down problems to build a solution

2. Two from:
   - Taking away detail that is not important...
   - ... so that you can focus on the detail that is important

3. One mark for each correct stage:

   List will need to be sorted into order 1, 2, 3, 15, 19, 24, 65, 87

LB	UB	MP
1	87	19
19	87	65

4. Any two from:
   - If the list is unsorted...
   - ... as a binary search will not work on an unordered list
   - If the list is small...
   - ... as it may take fewer passes through the data, especially if the ite

5. 5, 23, 1, 12, 3, 78, 2, 11 (1)

   1, 5, 12, 23, 2, 3, 11, 78 (1)

   1, 2, 3, 5, 11, 12, 23, 78 (1)

6. Wi[illegible]ra space cannot be used (1)

7. Example algorithm could be:
   - Last = length(array)
   - temp = array[0]
   - array[0] = array[last]
   - array[last] = temp
   - return array

Chapter 2: Programming

1. Any two from:
   - Questions or decisio[illegible]gorithm
   - A way of c[illegible]ple paths in an algorithm
   - d[illegible]endent on a conditional element

2. Any one of the following points:
   - Arrays can only have elements of the same data type (1) whereas re
   - 1-D arrays are one dimensional (1), whereas records are usually two

3. Any two from:
   - A syntax error could be caused by the wrong spelling of a key word
   - A syntax error could be caused by missing punctuation or wrong ind
   - A syntax error could be caused by failure to declare a variable
   - A logic error is more difficult to find as the code looks correct
   - A logic error will occur in code that runs correctly, but the wrong re
   - A logic error is caused by incorrect operators or not understanding

4. Any four from:
   - They could use input validation...
   - ... this will limit the data entered into the program, making it more
   - They could use input sanitisation...
   - ... this will remove any common unwanted data from the data
   - They could use authentication...
   - ... this will help stop unauthorised access to the program

5. 1 mark for initialising array
   1 mark for use of a counting loop
   1 mark for writing input to an array
   1 mark for correct selection of increased temperature
   1 mark for correct selection of decreased temperature
   1 mark for suitable output messages

   Example algorithm:

```
array babyTemp[14]
for x = 1 to 14
    babyTemp[x] = input("Enter baby temperature")
    if babyTemp[x] <36.5 then
                print("This baby is too cold")
    elseif babyTemp[x]  >37.5 then
                print("This baby is too hot")
    else
                print("Baby temperature is fine")
next x
```

6 a) 1 mark for initialising array for student names
   1 mark for initialising array for each test score
   1 mark for using a counting loop
   1 mark for writing student name to array
   1 mark for writing each test score to array
   1 mark for correctly validating each test score (must keep validating
   1 mark for suitable output messages

   NOTE: An alternative solution would be to use a 2D array, which sh
   if demonstrated.

Example algorithm:

```
array studentName [20]
array test1Scores [20]
array test2Scores [20]
for x = 0 to 19
    studentName[x] = input ("Enter the studen
    test1Score[x] = input ("Enter the student
    test1Score = false
    wh  e test1ScoreValid == false
        if test1Score[x] >=0 AND <=15 then
            print ("Test score accepted")
            test1ScoreValid = true
        else
            test1Score[x] = input ("The maximum
            15, please enter a valid mark")
    endwhile
    test2Score[x] = input ("Enter the student
    test2ScoreValid = false
    while test2ScoreValid == false
        if test1Score[x] >=0 AND <=20 then
            print ("Test score accepted")
            test2ScoreValid = true
        else
            test1Score[x] = input ("The maximum
            20, please enter a valid mark")
    endwhile
ne
```

b) 1 mark for totalling method variable setup for each test

1 mark for correct totalling of each test

1 mark for correct totalling of each score for a student

1 mark for correct output of student name and total test score

1 mark for class size stored as a constant

1 mark for correct calculation of average for each test (must be outs

1 mark for output of average for each test (must be outside loop)

NOTE: Alternative answers should be awarded all relevant marks if are demonstrated.

Example algorithm:

```
array studentName [20]
array test1Scores [20]
array test2Scores [20]
CONST classSize = 20
test1Total = 0
test2Total = 0
for x = 0 to 19
```

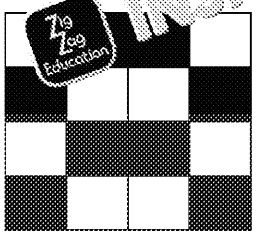
```
        studentName[x] = input ("Enter the studen
        test1Score[x] = input ("Enter the student
        test1ScoreValid = false
        while test1ScoreValid == false
            if test1Score[x] >=0 AND <=15 then
                print ("Test score accepted")
                test1Total = test1Total + test1Scor
                test1ScoreValid = true
            else
                test1Score[x] = input ("The maximum
                15, please enter a valid mark")
        endwhile
        test2Score[x] = input ("Enter the student
        test2ScoreValid = false
        while test2ScoreValid == false
            if test1Score[x] >=0 AND <=20 then
                print ("Test score accepted")
                test2Total = test2Total + test2Scor
                test2ScoreValid = true
            else
                test1Score[x] = input ("The maximum
                20, please enter a valid mark")
        endwhile
        total = test1Score[x] + test2Score[x]
        print (student[x], total)
    next x
    test1Average = test1Total/classSize
    test2Average = test2Total/classSize
    print ("The average score of test 1 is", test
    print ("The average score of test 2 is", test
```

Chapter 3: Data Representation

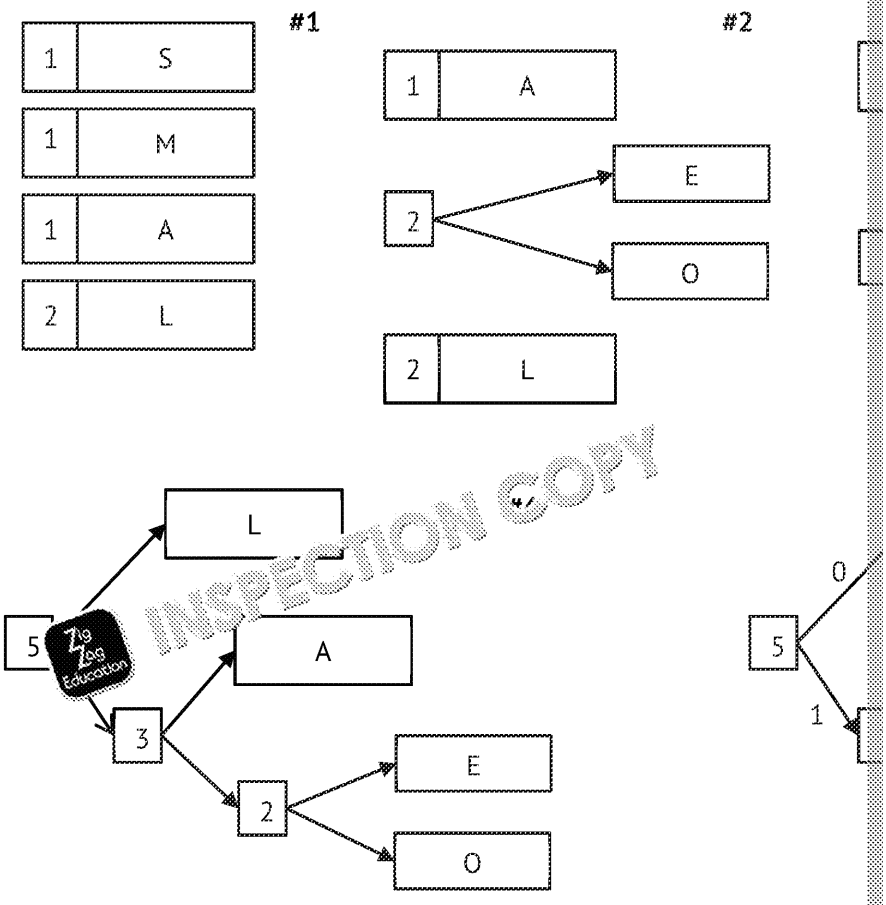
1. 1 mark for correct working, 1 mark for correct answer
   - 128 + 32 + 16 + 1
   - = 177

2. 1 mark for correct working, 1 mark for correct answer
   - 1011 = 11, 0001 = 1
   - 11 = B
   - =B1

3. 1 mark for each row



4. 01010000 (1)
5. 150x10x8 (1) = 12000 bits (1) = 1500 bytes (1). Award full marks for in
and stating the answer directly in bytes in the second.
6. Huffman trees (1), as written text is not compressed well using RLE (1)
7. Four from:
   - The sample frequency can be increased
   - ... this means that more sample[illegible] be taken at regular intervals, c
   - The sample size could be increased...
   - ... this would allow for a greater range of values to be measured
8. 1 [illegible] for each step. The order should be ascending, but may be differe



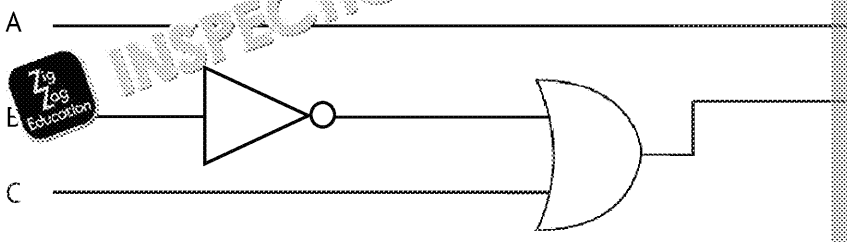
Chapter 4: Computer systems

1. Any two from:
   - It keeps track of each memory location
   - It looks to see whether a memory lo[illegible] available to be used in
   - It will decide which proces[illegible] memory allocated to it at any
2. Any three from:
   - Providing an interface
   - Managing multitasking
   - Peripheral management
   - Driver management
   - User management
   - File management

3. Four from:

- If either input into the gate is 1...
- ... the output of the gate will be 1
- If no input into the gate is 1...
- ... the output will be 0

4. 1 mark for each correct logic gate:



5. Three from:

- The CPU fetches the instruction and data needed into the CPU
- The CPU then decodes the instruction using an instruction set
- The CPU then executes the instruction, carrying out any calculations

6. Any two from:

- She could increase the clock speed of the processor, e.g. to 4 GHz...
- ... this would mean that more instructions could be carried out per second
- She could increase the number of cores, e.g. to dual core...
- ... this would mean that instructions could be carried out simultaneously
- She could increase the amount of RAM available, e.g. to 8 GB ...
- ... so that more instructions can be held in memory to be processed
- ... to limit the need for virtual memory

7. 1 mark for RAM, 1 mark for ROM, any two from:

- RAM is volatile
- ROM is non-volatile
- The contents of RAM can be changed
- The contents of ROM are not (normally) changed
- RAM stores the programs and data that are currently in use
- ROM stores the programs to boot up the computer

8. 1 mark for suitable storage device, 2 marks for reason:

- SD card / micro SD card
- Large storage capacity
- Has no moving parts so more durable
- Small and compact to fit into the device

9. Any two from:
   - High-level languages are closer to human language
   - Low-level languages are closer to computer language
   - High-level languages use English statements to construct a program
   - Low-level languages often use mnemonics to construct a program
   - In high-level language a line of program could perform many tasks
   - In low-level language a line of code will perform one task

10. Any combination up to 6 marks:
   - Assembler translates assembly language into machine code
   - Assembler uses words that have numerical equivalents
   - Assembler has 2 parts an operator and operand
   - Compilers translate high level languages into executable programs
   - Compilers translate into machine code that will be executed later
   - Interpreters translate high level languages one line at a time
   - Interpreters run each line in turn as it is translated
   - Interpreters need to be running on the target machine, where a compiler does not

Chapter 5: Computer Networks

1. Any two from:
   - Resources can be shared
   - Files can be accessed from any computer in the network
   - Peripherals can be shared
   - Servers can be set up as a central control
   - Communication can be sent to computers in the network

2. Any four from:
   - A LAN covers a small geographical area
   - A WAN covers a larger geographical area
   - A LAN is constructed using a company's/individual's own infrastructure
   - A WAN often uses external infrastructure
   - A LAN can have a very high speed of data transfer, as much as 1 Gbps
   - A WAN has a more limited speed of data transfer, normally restricted

3. Star network (1)

4. Any two from:
   - Only one computer can send data at a time
   - Slow if there are a large amount of devices
   - Communication is affected if the central bus is damaged

   (Accept other alternatives)

5. Occurs when to computers try to send data over the same cabling (1) at

6. Any two from:
   - Firewall (1) – controlling the traffic that enters and leaves a networ
   - MAC address filtering (1) – controlling the hardware that can conne
   - Encryption (1) – encrypting the files on a network so if they are acc
   - Authentication (1) – only letting certain people gain access using p

7. Any four from:
   - The application layer codes and distributes the data
   - The application layer makes sure the data is in a suitable format for
   - The transport layer manages the connections between devices using
   - The transport layer carries out any error detection and correction
   - The Internet layer facilitates the exchange of data across networks
   - The Internet layer is used to establish the route of a data packet
   - The network layer manages the transmission media for the local ne
   - The network layer makes sure the network hardware is operational

Chapter 6: Cybersecurity

1. Two from:
   - It is when simulations of potential attacks are carried out on a syste
   - It can be carried out by individuals or an automated software

2. Any two from:
   - Network policies could be put in place to provide guidance on what
     place and be trained
   - Malware software could be installed to search a network for m
   - A firewall could be set up to control traffic into and out of a networ
   - Account authentication could be put in place to help stop unauthori
   - All data stored could be encrypted so that it would be of no use sho

3. To stop people from automatically signing up to websites using bots (1
   humans can read (1).

4. One from:
   - Phishing email

5. Any four from:
   - People may not abide by network policies...
   - ... they could leave their computer unlocked when away from their d
   - ... they may give their login details to someone else
   - People may be subject to social engineering...
   - ... they could unknowingly give their details to a hacker
   - ... they could be persuaded to carry out an activity that will aid hack
   - People may download malware...
   - ... they may click on a link or a download that infects the system

6. As if a password is stolen, the thief has full access to the system (1). An
2-factor authentication (1), where another system is used such as biom

7. One from:
   - Cost

Chapter 7: Relational Databases and Structured Query L

1. A primary key uniquely identifies a record. A foreign key is used to for

2. Me ID

3. 4 (1) and 5 records (1)

4. No repeated or redundant data (1). No chances of data inconsistency (

5. SELECT FirstName, Surname (1)
   FROM Member (1)
   WHERE Age = 17 (1)
   ORDER BY LastName ASC (1)

6. DELETE from Member (1)
   WHERE MemberID = 'DE456' (1)

Chapter 8: Consequences of Digital Technology on Soci

1. Any two from:
   - To stop people from sharing their software between multiple comp
   - To stop people from having downloaded software illegally

2. People may not give permission to be filmed (1), use of facial recogniti
privacy (1).

3. Any two from:
   - A person giving the public the ability to legally share and develop t
   - Different types of licence allow different levels of sharing and deve
   - Any accurate example of a licence

4. To stop them from malfunctioning / being hacked (1)

5. Any four from:
   - People may not understand how to set their privacy settings to the
   - ... this could result in many people being able to view content that
   - ... this could result in details from their profile being used in identit
   - A corporation could monitor a person's social media activity...
   - ... could result in providing patterns in their location and expos
   - ... this could result in personal information being collected and the
   - A person could leave themselves exposed to cyberbullying...
   - ... by revealing information about themselves on social media

6. **Banded response question**

High mark band (6–8 marks)	The candidate is able to demonstrate a thorough k throwaway technology, giving a wide range of con able to apply their knowledge to the context provi give a balanced argument. The information provid accurate. Relevant examples will be provided
Mid mark band (3–5 marks)	The candidate is able to demonstrate a reasonable throwaway technology, giving a range of considera application of their knowledge to the contex given a reasonable attempt at a balanced argumen will be reasonably detailed and mostly accurate.
Low mark band (1–2 marks)	The candidate is able to demonstrate a basic know technology, with limited considerations. The candi their knowledge to the context provided. The cand a balanced argument. The information provided w

Possible considerations:

Stakeholders

- The general public
- Environmental activists
- The government
- Technology companies

Ethics

- Increas
- Toxic w
- Increas
- The nee

Technology

- Any throwaway device, e.g. mobile phones, tablets, wearable technologies

Solutions

- Govern
- Recycli
- Educati
- Any rea

Sample answer:

Technology companies are constantly looking for ways to develop the next big ... ensure their future sales and the success of their business. When they have dev... actively encourage and persuade the general public that they must have their la... affected by the desire for new technology, such as a new mobile phone or a new... current technology they have when the new technology is purchased.

By creating a throwaway attitude to technology, we are creating a number of pr... the environment. When we throw the technology away it can go into landfill. ... landfill and this is adding to a bigger issue. There are also present harmful me... toxic waste into the ground. Another problem this can create is an increase in c... powerful devices, technology companies create the need for more electricity to ... more electricity increases the rate of carbon emissions into the environment.

The government could look to solve the possible solutions to the problems create... could look to offer recycling incentives to get people to recycle their old devices ... which could be passed on to people who are less fortunate, who may ... The government could also look to encourage companies to develop more powe... carbon emission level; they could offer funding to companies who are willing to

This sample answer covers the four key areas listed above. It also demonst... GCSE level about the impact of constant developments in new technology. ... this a high-band mark.