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Higher Computing Science

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# Section 1 - Data Representation

## Topic 1 - Numbers (Binary and Denary)

###

|  |
| --- |
| Definitions**Binary number**: Binary (or base-2) a numeric system that only uses two digits — 0 and 1. Computers operate in binary, meaning they store data and perform calculations using only zeros and ones. A single binary digit can only represent True (1) or False (0) in boolean logic.**Denary number**: Denary, also known as "decimal" or "base 10," is the standard number system used around the world. It uses ten digits (0, 1, 2, 3, 4, 5, 6, 7, 8, and 9) to represent all numbers. Denary is often contrasted with binary, the standard number system used by computers and other electronic devices.The first two letters in denary ("de") are an abbreviated version of "dec" which is a Latin prefix meaning "ten." The Latin prefix "bi" means two. Therefore, the denary system contains ten digits, while the binary system only contains two (0 and 1).**Integer**: An integer is a whole number (not a fraction) that can be positive, negative, or zero. Therefore, the numbers 10, 0, -25, and 5,148 are all integers. Unlike floating point numbers, integers cannot have decimal places.**Floating point numbers**: As the name implies, floating point numbers are numbers that contain floating decimal points. For example, the numbers 5.5, 0.001, and -2,345.6789 are floating point numbers. Numbers that do not have decimal places are called integers. Computers recognize real numbers that contain fractions as floating point numbers.**Real number**: A real number is any positive or negative number. This includes all integers and all rational and irrational numbers. Rational numbers may be expressed as a fraction (such as 7/8) and irrational numbers may be expressed by an infinite decimal representation (3.1415926535...). Real numbers that include decimal points are also called floating point numbers, since the decimal "floats" between the digits. |

###

###

### National 5 Revision - converting between Binary and Denary numbers

#### Converting Binary to Denary

Positive integers are stored in the computer using their place values and can be used to convert Binary to Denary.

Example:

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

64 + 16 + 4 + 2 = 86

####

#### Converting Denary to Binary

Positive integers are stored in the computer using their place values and can be used to convert Binary to Denary.

1. Start at the *left-most bit*
2. If the number to be converted is greater than the column heading
	1. Put a 1 in the column
	2. Reduce the number by the column heading
3. Else
	1. Put a 0 in the column
4. Move onto next column
5. Repeat from step 2

### National 5 Revision - converting between Binary and Denary numbers QUESTIONS

1. Convert the following numbers from binary to denary:

|  |  |  |
| --- | --- | --- |
|  | **Binary** | **Denary** |
| **a** | 0001 1101 |  |
| **b** | 1011 1011 |  |
| **c** | 0110 0110 |  |
| **d** | 1011 0111  |  |
| **e** | 0010 1101 |  |
| **f** | 0011 1111 |  |
| **g** | 1111 1101 |  |
| **h** | 1010 1010 |  |

1. Convert the following numbers from denary to binary:

|  |  |  |
| --- | --- | --- |
|  | **Binary** | **Denary** |
| **a** |  | 145 |
| **b** |  | 163 |
| **c** |  | 25 |
| **d** |  | 68 |
| **e** |  | 14 |
| **f** |  | 123 |
| **g** |  | 85 |
| **h** |  | 245 |

## Topic 2 - Negative Numbers (Two’s Complement)

##

|  |
| --- |
| **Definitions****Negative number**: A negative number is a real number that is less than zero. Negative numbers represent opposites. If positive represents a movement to the right, negative represents a movement to the left. If positive represents above sea level, then negative represents below sea level.**Two’s Complement**: In Two’s complement, the most significant bit (the leftmost bit) indicates whether the number is positive or negative. If the most significant bit is a 1 then it is a negative number, if it is a 0 then it is positive. |

### Two’s Complement - storing negative denary numbers

To convert a negative denary number into its Two’s Complement representation you:

1. work out the positive binary number
2. invert all the bits (so a 1 becomes a 0 and a 0 becomes a 1)
3. then add 1

Example:

To convert -17 to Two’s Complement:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step** | **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |
| **1** -positive binary | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **2** - invert all the bits | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| **3** - add 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |

### Two’s Complement - storing negative denary numbers QUESTIONS

1. Convert the following negative numbers from denary to binary:
	1. -25

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step** | **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |
| **1** -positive binary |  |  |  |  |  |  |  |  |
| **2** - invert all the bits |  |  |  |  |  |  |  |  |
| **3** - add 1 |  |  |  |  |  |  |  |  |

* 1. -87

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step** | **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |
| **1** -positive binary |  |  |  |  |  |  |  |  |
| **2** - invert all the bits |  |  |  |  |  |  |  |  |
| **3** - add 1 |  |  |  |  |  |  |  |  |

* 1. -129

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step** | **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |
| **1** -positive binary |  |  |  |  |  |  |  |  |
| **2** - invert all the bits |  |  |  |  |  |  |  |  |
| **3** - add 1 |  |  |  |  |  |  |  |  |

### Two’s Complement - converting negative binary numbers to denary

To convert a negative binary number into its Denary representation you:

1. Look at *leftmost bit* to see if it is negative or not
	1. 1 indicates negative:
		1. Subtract 1
		2. Invert all the bits
		3. Write a -ve sign
	2. 0 indicates positive:
		1. Write a +ve sign
2. Add to get the denary number
3. Write the denary number with the correct sign

Example:

To convert 11001101 in Two’s Complement to denary:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step** | **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |
| **1** -LMB is 1, so negative | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| **1a i** -subtract 1  | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| **1 a ii** - Invert all the bits | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| **1 a iii/ 1 b i** - write the sign | - |
| **2** - add to get denary | 32 + 16 + 2 + 1 = 51 |
| **3** - write with sign | -51 |

### Two’s Complement - converting negative binary numbers to denary QUESTIONS

1. Convert the following Two’s Complement numbers from binary to denary:
	1. 1001 1001

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step** | **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |
| **1** -LMB is 1, so negative |  |  |  |  |  |  |  |  |
| **1a i** -subtract 1  |  |  |  |  |  |  |  |  |
| **1 a ii** - Invert all the bits |  |  |  |  |  |  |  |  |
| **1 a iii/ 1 b i** - write the sign |  |
| **2** - add to get denary |  |
| **3** - write with sign |  |

* 1. 1100 1101

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Step** | **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |
| **1** -LMB is 1, so negative |  |  |  |  |  |  |  |  |
| **1a i** -subtract 1  |  |  |  |  |  |  |  |  |
| **1 a ii** - Invert all the bits |  |  |  |  |  |  |  |  |
| **1 a iii/ 1 b i** - write the sign |  |
| **2** - add to get denary |  |
| **3** - write with sign |  |

### Two’s Complement - range of positive and negative integers

|  |
| --- |
| **Definitions****Range**: The range is the distance from the lowest to the highest in a set of numbers. For Two’s Complement, we need to identify the lowest negative number and the highest positive number that can be stored. |

To find the range of a Two’s Complement number, follow these steps.

1. Calculate the range of numbers as if it were all positive
2. Half it - this will be the lowest negative number
3. Subtract 1 to get the highest positive number
4. Write the range

Example:

For a 4 bit number

|  |  |
| --- | --- |
| **Step** |  |
| **1** -The range if not Two’s Complement | 4 bits can store 16 different numbers |
| **2** - Half it for lowest -ve number  | 16/2 = 8, so lowest negative value is -8 |
| **3** - Subtract one for highest +ve number  | 8-1 = 7, so highest positive value is +7 |
| **4** - write the range  | The range of numbers that can be represented using 4 bits in Two’s Complement is -8 to +7 |

This can be done mathematically as well:

Lowest negative value: -(2bits)/2 = -(24)/2 = -(16)/2 = -8

Highest positive value: +(2bits)/2 - 1 = +(24)/2 - 1 = +16/2 - 1 = +8-1 = +7

### Two’s Complement - range of positive and negative integers QUESTIONS

1. What range of numbers can be represented with the following number of bits in Two’s Complement:
	1. 5 bits

|  |  |
| --- | --- |
| **Step** |  |
| **1** -The range if not Two’s Complement |  |
| **2** - Half it for lowest -ve number  |  |
| **3** - Subtract one for highest +ve number  |  |
| **4** - write the range  |  |

* 1. 8 bits

|  |  |
| --- | --- |
| **Step** |  |
| **1** -The range if not Two’s Complement |  |
| **2** - Half it for lowest -ve number  |  |
| **3** - Subtract one for highest +ve number  |  |
| **4** - write the range  |  |

## Topic 3 - Real Numbers

### Denary Floating Point Representation using Mantissa and Exponent

|  |
| --- |
| **Definitions****Integer**: An integer is a whole number (not a fraction) that can be positive, negative, or zero. Therefore, the numbers 10, 0, -25, and 5,148 are all integers. Unlike floating point numbers, integers cannot have decimal places.**Floating point numbers**: As the name implies, floating point numbers are numbers that contain floating decimal points. For example, the numbers 5.5, 0.001, and -2,345.6789 are floating point numbers. Numbers that do not have decimal places are called integers. Computers recognize real numbers that contain fractions as floating point numbers.**Real number**: A real number is any positive or negative number. This includes all integers and all rational and irrational numbers. Rational numbers may be expressed as a fraction (such as 7/8) and irrational numbers may be expressed by an infinite decimal representation (3.1415926535...). Real numbers that include decimal points are also called floating point numbers, since the decimal "floats" between the digits.**Mantissa**: The mantissa is the part of a number located after the point. It is normally used when dealing with *scientific notation*.**Exponent**: The exponent, in *scientific notation* is the power that is used to determine how far the point has moved. |

The structure of a floating point number is:

mantissa x baseexponent

To work out the mantissa and exponent you need to:

1. move the point all the way so the number is a fractional value
2. the entire number without the point is the mantissa
3. the number of places the point was moved (expressed as a two’s complement binary number) is the exponent.

Example:

|  |  |  |  |
| --- | --- | --- | --- |
| Original Number | Scientific Notation | Mantissa | Exponent |
| 217.46 | 0.21746 x 103 | 21746 | 3 |

### Denary Floating Point Representation using Mantissa and Exponent QUESTIONS

1. Complete the table:

|  |  |  |  |
| --- | --- | --- | --- |
| Original Number | Scientific Notation | Mantissa | Exponent |
| 217.46 | 0.21746 x 103 | 21746 | 3 |
| 3524.789 |  |  |  |
| 212256.3457 |  |  |  |
|  | 0.5689 x 102 |  |  |
|  | 0.254784169 x 105 |  |  |
|  |  | 123456789 | 4 |
|  |  | 64894368979146 | 6 |

###

Binary Floating Point Representation using Mantissa and Exponent

#### Large numbers

Consider the denary number 1845.75.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2048 | 1024 | 512 | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 0.5 | 0.25 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |

To convert this to a Floating Point Notation using a 16 bit mantissa and 8 bit exponent would move the point before the first 1. The remaining 16 bits would be made 0.

1110 0110 1011 1***000***

As the point has moved 11 places to the left, the exponent is 11, which is 0000 1011 in 8 bit binary.

This means the original number would be stored as

1110 0011 0101 1100 x 2 0000 1011

#### Small numbers

Consider the denary number 0.1875.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 64 | 32 | 16 | 8 | 4 | 0.5 | 0.25 | 0.125 | 0.0625 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

To convert this to a Floating Point Notation using a 16 bit mantissa and 8 bit exponent would move the point before the first 1. The remaining 16 bits would be made 0.

11***00 0000 0000 0000***

As the point has moved 2 places to the right, the exponent is -2, which needs to be converted to Two’s Complement, as it is negative.

 Convert to binary Invert bits Add 1

2 = 0000 0010 1111 1101 1111 1110

This means the original number would be stored as

1100 0000 0000 0000 x 2 1111 1110

###

Binary Floating Point Representation using Mantissa and Exponent QUESTIONS

1. Convert the following to 16 bit mantissa and 8 bit exponent notation:
	1. 2045.125

|  |
| --- |
|  |

* 1. 3165.75

|  |
| --- |
|  |

* 1. 4267.875

|  |
| --- |
|  |

1. Convert the following binary numbers to 16 bit mantissa and 8 bit exponent notation, using Two’s Complement for the exponent.
	1. 0.00111

|  |
| --- |
|  |

* 1. 0.000101

|  |
| --- |
|  |

* 1. 0.00011101

|  |
| --- |
|  |

### Range and Precision of Floating Point Representation

|  |
| --- |
| **Definitions****Range**: The range is the distance from the lowest to the highest in a set of numbers. In this context, it is about the amount of numbers that can be stored in different numbers of bits.**Precision**: The precision of the binary number is how accurately it can reproduce the original denary number. As storage space may be limited, some data may be lost, making the binary number less precise. |

The number of bits allocated to a floating point number is usually fixed. For example: if you had a fixed 40 bits for storing a floating point number then 32 bits could be allocated to the mantissa leaving 8 bits for the exponent.

* The number of bits allocated to the **mantissa** affects the **precision** of the number.
* The number of bits allocated to the **exponent** affects the **range** of numbers that can be stored.

Example:

Consider the denary number 145.25

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 0.5 | 0.25 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |

Using 16 bits for mantissa and 8 bits for exponent gives:

1001 0001 0100 0000 x 20000 1000

However, if only 8 bits were available for the mantissa, it would be shortened to:

 1001 0001 x 20000 1000

Clearly some information has been lost. When converted back, this would give the denary value of 145. Although close, it is not exactly the same as the original denary number, so is **less precise.** Reducing the number of bits for the mantissa reduces the precision of the number. (The opposite is also true - increasing the number of bits for the mantissa increases the precision)

Similarly, increasing the size of the exponent will increase the range of numbers that can be stored, and reducing the size of the exponent will decrease the range of numbers that can be stored.

### Range and Precision of Floating Point Representation QUESTIONS

1. Create a simple diagram explaining that:
	1. Increasing the mantissa improves the precision of the number
	2. Decreasing the mantissa decreases the precision of the number
	3. Decreasing the exponent increases the range of numbers that can be stored
	4. Decreasing the exponent increases the range of numbers that can be stored

|  |
| --- |
|  |

##

## Topic 4 - Storing Text

### Extended ASCII and UNICODE

|  |
| --- |
| **Definitions****ASCII**: **A**merican **S**tandard **C**odefor **I**nformation **I**nterchange. One method for representing printable and non-printable characters. ASCII uses 7-bits, so can store a maximum of 128 different characters.**Extended ASCII**: Extended ASCII uses 8-bits to store the character, which doubles the number of characters to 256 different characters.**Unicode**: Unicode is a development of ASCII that allows for 16-bits per character, meaning it can represent 65 536 different characters. This is often referred to as UTF-16. A newer version of Unicode, UTF-32, allows 32 bits per character.**Printable Character**: A character that is visible to the user. Any letters, numbers or punctuation marks are printable characters.**Non-printable Character**: Any character that does not display in a form normally visible to the user. Examples include <return>, <tab>, <end of line> and <end of file>**Character Set**: All the characters that can be stored in a particular representation. |

When you are using a program and you press a key on the keyboard the program has to have some way of identifying which key you pressed.

Each character on the keyboard has a unique binary code allocated to it.

This is called ASCII - **A**merican **S**tandard **C**odefor **I**nformation **I**nterchange.

ASCII code includes:

* Non-printable characters: <return>, <tab>
* Numbers: 0-9
* Upper and Lower Case Letters: A-Z, a-z
* Punctuation and other symbols: $, %, !, ?, @

All of the above are examples of the **character set**. This is the group of letters and numbers and characters that a computer can represent and manipulate.

Control characters include keys such as RETURN, TAB and DELETE. They are the first 32 characters in ASCII. These are used to send a control signal to a printer e.g. <backspace> or <new line>. Sometimes control characters are referred to as ‘**non-printable characters**’.

More recently, the number of characters has required to be extended, as increasingly we communicate using foreign characters (such as à, ñ, û). To help, ASCII was developed further to create UNICODE, which uses 16 bits to represent the characters.

The disadvantage of this is that Unicode requires twice as much storage as Extended ASCII, but significantly increases the number of potential characters from 256 to 65 536 different characters. This is often referred to as UTF-16.

A newer version of Unicode, UTF-32, allows for storage of 4 294 967 296 different characters, but again, requires double the storage of UTF-16.

### Extended ASCII and UNICODE QUESTIONS

1. Complete the table below detailing advantages and disadvantages of Extended ASCII and Unicode (UTF-16):

|  |  |  |
| --- | --- | --- |
|  | **ASCII** | **Unicode (UTF-16)** |
| **Storage requirements** |  |  |
| **Number of characters** |  |  |

##

## Topic 5 - Storing Graphics

### Bitmap and Vector Graphics

|  |
| --- |
| **Definitions****Pixel**: **Pic**ture **El**ement - the most basic component of any computer graphic.**Bitmap**: a map of pixels, where each pixel has a binary number, determining its colour.**Resolution**: The resolution of a bitmap image is a measure of the number of pixels in the image. **Colour depth**: The colour depth of a bitmap image is the number of bits assigned to each pixel, and hence determines the maximum number of different colours that can be used in the image.**Vector graphics**: use 2D point located polygons to represent images in computer graphics. Each of these points has a definite position on the x- and y-axes of the work plane and determines the direction of the path; further, each path may have properties, including such values as stroke color, shape, curve, thickness, and fill. |

###

### Bitmap and Vector Graphics QUESTIONS

1. Try drawing the same image in a Bitmap graphics package and in a Vector graphics package. Complete the table below comparing Bitmap and Vector Graphics:

|  |  |  |
| --- | --- | --- |
|  | **Bitmap** | **Vector** |
| **Storage requirements** |  |  |
| **Resolution** |  |  |
| **Zooming** |  |  |
| **Layering** |  |  |
| **Editing** |  |  |
| **Scaling** |  |  |

# Section 2 - Computer Structure

## Topic 6 - The Fetch-Execute Cycle

|  |
| --- |
| **Definitions****Bus**: a collection of wires inside the computer that are used to transfer information and send signals. **Address Bus**: a collection of wires connecting the processor to memory, used to inform memory which uniquely addressed location is being used. The Address Bus is uni-directional (the address only travels one-way - from processor to memory). The address bus is made up of parallel wires each carrying a single bit. **Data Bus**: a collection of wires connecting the processor to memory, used to inform memory what data is to be sent/ received from memory. The Data Bus is bi-directional (the data can travel both ways - to and from memory). The data bus is made up of parallel wires each carrying a single bit. **Control Bus**: The control bus is made up of individual lines with specific functions giving instructions to the rest of the system from the control unit. There are a number of important lines on the control bus:**Read line**: used to initiate a memory read operation which reads the contents of a memory location into the processor**Write line**: used to initiate a memory write operation which writes an item of data from the processor into a memory location**Clock line**: sends a series of pulses into the processor to synchronize events. The time interval between pulses is called a clock cycle.**Registers**: storage locations inside the processor that are used to hold instructions or data.**Address Register**: used to hold the address of the next instruction or piece of data to be sent to or received from memory.**Data Bus**: used to hold the next piece of instruction or piece of data to be sent to memory **or** just received from memory.**Instruction Register**: a register used to keep track of where a program is in its execution. |



### Memory Read operation

1. The processor sets up the address bus with required memory address.
2. The processor activates the read line on the control bus.
3. The contents of the memory location are transferred along the data bus into the data register.

### Memory Write operation

1. The processor sets up the address bus with required memory address.
2. The processor sets up the data bus with the data to be written to memory.
3. The processor activates the write line on the control bus
4. The data is transferred along the data bus to the storage location in the computer’s memory

### Summary of the Fetch-Execute cycle

1. The processor sets up the address bus with the required address.
2. The processor activates the read line on the control bus.
3. An instruction is fetched from the memory location using the data bus and stored in the instruction register
4. The instruction in the instruction register is interpreted by the processor, decoded and carried out.
5. This process continues until the program is finished.

### Fetch-Execute Cycle QUESTIONS

1. Complete the diagram below to explain the Fetch-Execute Cycle:

 

1. Put the steps of the Fetch-Execute Cycle in the correct order.

|  |  |  |
| --- | --- | --- |
| **Wrong order** |  | **Correct Order** |
| Active the read line |  |  |
| Decode and carry out instruction |  |  |
| Address bus set up with address |  |  |
| Repeat until end of program |  |  |
| Instruction moved along data bus and into instruction register |  |  |

## Topic 7 - Factors affecting system performance

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| **Definitions****Cores**: A multi-core processor is a single computing component with two or more independent processing units called cores, which read and execute program instructions. The instructions are ordinary CPU instructions (such as add or move data) but the single processor can run multiple instructions on separate cores at the same time. **Dual core**: a multi-core processor with exactly two independent processors. **Quad core**: a multi-core processor with exactly four independent processors. **Cache**: a component that stores data so future requests for that data can be served faster; the data stored in a cache might be the result of an earlier computation, or the duplicate of data stored elsewhere. **Clock speed**: The clock rate typically refers to the frequency at which a chip like a central processing unit (CPU), one core of a multi-core processor, is running and is used as an indicator of the processor's speed. It is measured in clock cycles per second. The clock rate of the first generation of computers was measured in hertz or kilohertz (kHz), but in the 21st century the speed of modern CPUs is commonly advertised in gigahertz (GHz). |

A number of factors can improve the performance of a computer system.

### Number of processors (cores)

This is the development of several sets of processor components in one microprocessor. A dual core processor has two separate CPU’s in one chip and a quad core processor has four separate CPU’s in one chip. The more cores a processor has, the more sets of instructions the processor can receive and process at the same time — this improves system performance. A dual core processor is not as fast as a single processor running at twice the speed, as it is not always possible to share some tasks equally between the cores. This reduces efficiency.

### Width of Data Bus

The data bus is a set of parallel wires that connects the processor with memory and other hardware devices. By increasing the data bus from 32 wires to 64 wires, the computer can transfer twice as much information at one time. Therefore, increasing the size of the data bus improves the system performance of the computer.

### Cache Memory

Cache memory is a small amount of fast accessible memory, usually on the same chip as the processor. The processor checks this for data or instructions before accessing the main memory. If it finds the data or instruction, then this is termed as a cache ‘hit’, resulting in an improved performance. If the instruction is not present, then a cache ‘miss’ occurs and a slower main memory is accessed. Many computers use multiple levels of cache, with small caches backed up by larger, slower caches. Multi-level caches operate by checking the fastest cache (level 1) first. If it has a match, the processor proceeds at high speed. If it does not have a match, it checks the next fastest cache (level 2) and so on.

### Clock Speed

This is the electronic unit that synchronises related components by generating pulses at a constant rate. Clock pulses are used to trigger components to take their next step. The clock rate is the frequency at which the clock generates pulses. The higher the clock rate, the faster the computer may complete a series of instructions. Different manufacturers measure the clock rate in different ways, so it is not always possible to do direct comparison between different processor manufacturers.

###

### Factors affecting system performance QUESTIONS

Steve and Gemma work together in a web development company, carrying out tasks such as manipulating spreadsheets, querying databases and making complex websites. They have always had very similar workrates, but since getting a new processor, Gemma is working faster than Steve.

Steve’s computer has the processor on the left, while Gemma’s computer has the processor on the right:

|  |  |
| --- | --- |
| **Processor**- Nanntel Core 16-bit m2-1700 Processor- Dual-core- 2.9 GHz- 3 MB cache | **Processor**- EDM 4-Core 32-bit 68x Processor- Quad-core- 3.9 GHz- 4 MB cache |
| *Steve’s Processor* | *Gemma’s Processor* |

1. Identify the following for each processor

|  |  |  |
| --- | --- | --- |
|  | **Steve’s processor** | **Gemma’s Processor** |
| **Number of cores** |  |  |
| **Data bus width** |  |  |
| **Amount of Cache memory** |  |  |
| **Clock Speed** |  |  |

1. With reference to all four factors that affect system performance, explain why Gemma is now working faster than Steve.

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# Section 3 - Environmental Impact of Intelligent Systems

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| **Definitions****Intelligent System**: An intelligent system is a machine with an embedded, Internet-connected computer that has the capacity to gather and analyze data and communicate with other systems. Other criteria for intelligent systems include the capacity to learn from experience, security, connectivity, the ability to adapt according to current data and the capacity for remote monitoring and management. |

## Topic 8 - Heating Systems

Smart heating systems use a variety of ways to control the amount of heat required in our homes. Using activity sensors, some smart systems learn the temperatures that you prefer in certain rooms and at what times. Monitoring the activity in rooms can mean that the smart system adjusts the heating up or down depending on whether there is unusual activity in the house. The thermostat is connected to wi-fi and can be manually controlled by using an app on your phone. This allows you to turn the heating system off if you are not going home or to turn it on so that it is at the optimum temperature if you are coming home early.

## Topic 9 - Traffic Control

Vehicles are considered one of the main contributing sources of greenhouse gas. Studies in the European Union showed that transport causes 25% of all carbon dioxide emissions. Vehicles consume greater amounts of fuel when they are constantly accelerating and braking in traffic jams. The optimum speed for low fuel consumption and low emissions is between 45 and 65 miles per hour. Intelligent transport systems use software and hardware, along with information and communications technologies, to improve the efficiency and safety of transport networks. They use a variety of information from cameras and sensors, along with control of traffic signals, to try to keep traffic moving, reducing the amount of harmful emissions. Cars with individual navigation systems use satellite information on traffic flow to guide drivers away from traffic congestion and on to more free-flowing routes.

## Topic 10 - Car Management Systems

A number of different car management systems are used to reduce the impact on the environment. Start-stop systems automatically shut down the engine when the car is not moving — this reduces the amount of time the engine spends idling, reducing fuel consumption and emissions. The car automatically re-starts when the accelerator is pressed, which is most advantageous for vehicles that spend significant amounts of time waiting at traffic lights or frequently come to a stop in traffic jams. Engine control units use sensors to ensure the engine’s air/fuel ratio can be controlled very accurately, ensuring optimum fuel consumption and a reduction of carbon dioxide emissions.

### Environmental Impact of Intelligent Systems QUESTIONS

1. Using the detail in Topics 8, 9 and 10 and your own research, create a mind map (or similar diagram) detailing the environmental impact of intelligent systems.

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# Section 4 - Security Risks and Precautions

## Topic 11 - Computer Misuse Act 1990

The Computer Misuse Act (1990) recognises the following as offences:

1. Unauthorised access to computer material.
2. Unauthorised access with intent to commit or facilitate a crime.
3. Unauthorised modification of computer material.
4. Making, supplying or obtaining anything which can be used in computer misuse offences.

### Unauthorised access to computer material

This is the lowest level of offence and is one that many of us might be guilty of at some stage in our school or working lives.

Have you ever found, guessed or used someone elses' password to log onto their user area? If you do this and then look at their files, even if you don't change, delete or damage anything, you are still guilty of accessing materials without authorisation - and this is illegal.

This offence carries the risk of being sentenced to six months in prison and/or a hefty fine.

### Unauthorised access with intent to commit or facilitate a crime.

The difference between this and the first offence is that the person gaining access to someone elses' system is doing so with the sole purpose of doing something illegal.

This might mean that they had to guess or steal the password in order to get into someone's user area or their bank account. They could do this by trial and error or by using special programs such as spyware or keylogging software, or they could use a relatively new technique called 'phishing'.

They might want to steal some company secrets or they might want to transfer some money out of your bank account into their own.

Anyone caught doing this risks up to a five year prison sentence and/or a hefty fine.

### Unauthorised modification of computer material.

Everyone deletes files from their own system, maybe they no longer need them or maybe they delete them by mistake. This is fine - there was no intent to cause any damage.

This offence relates to the deletion or changes made to files with the intent to cause damage to an individual or company. The difference is 'the intent to cause damage'.

This offence also covers purposely introducing viruses to other peoples' systems.

If you knowingly transmit a virus to others, you are guilty under this section of the Computer Misuse Act.

This offence carries a penalty of up to five years in prison and/or a fine.

### Making, supplying or obtaining anything which can be used in computer misuse offences.

#### Making

This includes the writing or creation of computer viruses, worms, trojans, malware, malicious scripts etc.

#### Supplying

This part covers the distribution of any of the above material whether you have created it yourself or obtained it from elsewhere. It is an offense to supply or distribute these files to others.

#### Obtaining

If you purposely obtain malicious files such as as computer viruses or scripts that you know could be used to damage computer systems then you have committed an offence under the Computer Misuse Act.

### Computer Misuse Act 1990 QUESTIONS

1. For each of the following scenarios, decide if an offence under the Computer Misuse Act 1990 has taken place. You will need to decide what part(s) of the act deal with the offence.
	1. Steve is going away on a course for a week, and Gemma will be picking up some of his work. Steve has an agreement in place with the Company IT Staff that Gemma can access his files. When he comes back, he finds that Gemma has deleted his client contact file.

|  |  |
| --- | --- |
| Has unauthorised access to computer material taken place? | Yes/No |
| Has unauthorised access with intent to commit a crime taken place? | Yes/No |
| Has unauthorised modification of computer data taken place? | Yes/No |
| Has the making, supplying or obtaining anything which can be used in computer misuse offences take place | Yes/No |
| **Has an offence taken place under the Computer Misuses Act 1990?** | **Yes/No** |

* 1. Gemma has started a new job, and realises that she has left some files at her old job that would be useful. While visiting Steve at her old job one day, she runs a piece of software from her pendrive that makes a copy of all her files and emails them to her new work.

|  |  |
| --- | --- |
| Has unauthorised access to computer material taken place? | Yes/No |
| Has unauthorised access with intent to commit a crime taken place? | Yes/No |
| Has unauthorised modification of computer data taken place? | Yes/No |
| Has the making, supplying or obtaining anything which can be used in computer misuse offences take place | Yes/No |
| **Has an offence taken place under the Computer Misuses Act 1990?** | **Yes/No** |

## Topic 12 - Security Risks

### Tracking Cookies

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| **Definitions****Cookie**: An HTTP cookie (also called web cookie, Internet cookie, browser cookie, or simply cookie) is a small piece of data sent from a website and stored on the user's computer by the user's web browser while the user is browsing.**Tracking Cookie**: Tracking Cookies are a specific type of cookie that are distributed, shared, and read across two or more unrelated websites for the purpose of gathering information or potentially to present customized data to you. |

A cookie is a small data file created when you access a website. These can be used to store your personal preferences or log in details so you don’t need to re-enter these details. A cookie is stored on the client rather than the server as they are personal to you.

Tracking cookies take this one step further. Your details are recorded and then transmitted back to the cookie’s author. Most are benign and are just gathering marketing information
On other occasions programmers can set the tracking cookie up to send them usernames and personal details. As well as concerns around identity theft, these cookies can be used to target users with personalised adverts.

### Tracking Cookies QUESTIONS

1. Tracking cookies can be created and used when browsing a website. Describe a security risk associated with tracking cookies.

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### Denial of Service (DoS) Attacks

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| **Definitions****Denial of Service Attack**: A denial-of-service (DoS) is any type of attack where the attackers (hackers) attempt to prevent legitimate users from accessing the service. In a DoS attack, the attacker usually sends excessive messages asking the network or server to authenticate requests that have invalid return addresses.**Symptoms**: What will happen that may allow a DOS attack to be identified as taking place.**Bandwidth**: the capacity of a wired or wireless network communications link to transmit the maximum amount of data from one point to another over a computer network or internet connection in a given amount of time - usually one second. Bandwidth describes the data transfer rate.**Domain Name Service (DNS)**: Short for Domain Name System (or Service or Server), a DNS is an Internet service that translates domain names into IP addresses. Because domain names are alphabetic, they're easier to remember. **IP Address**: a unique string of numbers separated by full stops that identifies each computer using the Internet Protocol to communicate over a network. |

Denial of service or "DoS" describes the ultimate goal of a class of cyber attacks designed to render a service inaccessible. The DoS attacks that most people have heard about are those launched against high profile websites, since these are frequently reported by the media. However, attacks on any type of system, including industrial control systems which support critical processes, can result in a denial of service.

When a website suffers a DoS attack, the apparent effect will depend on your perspective. For the average user, it appears that the site has simply stopped displaying content. For businesses, it could mean that the online systems they depend upon have ceased to respond. The symptoms of a DoS attack against industrial control systems may include the inability to retrieve sensor data, or control critical processes.

DoS attacks can range in duration and may target more than one site or system at a time. An attack becomes a 'distributed denial of service', referred to as “DDoS”, when it comes from multiple computers (or vectors) instead of just one. This is the most common form of DoS attack on websites.[[1]](#footnote-1)

####

#### Symptoms of DOS attacks

* slows performance of the servers under attack and can completely halt any other access
* inability to access resources held on the server

#### Effects of DOS attacks

* Genuine users are not able to access resources, so may not be able to find the information or carry out the actions they need
* Businesses may not be able to carry out time critical actions. They may also suffer reputational damage. Customers may chose to use a competitor.

#### Costs of DOS attacks

* If unable to complete business in time, there may financial loss in that contracts may not be paid.
* Employees may require to work overtime to fix the faults, resulting in additional costs for pay.

#### Type of fault caused by DOS attacks

* Bandwidth Consumption - Flood of requests fills the connection up to their limit so no other requests can get through. The effect only lasts as long as the attack is maintained.
* Resource Starvation - Requests each use a little bit of other resources, like disk space, until the server runs out and is no longer able to function correctly.
* Domain Name Service (DNS) Attacks - these attack the servers that route internet traffic so can impact on multiple websites.

#### Reasons for DOS attacks

* Financial - The attacker may demand payment to stop the attack
* Political - The attacker may wish to take down government websites to protest at government actions
* Personal - An individual may have a grievance against a company and decide to enact revenge.

## Denial of Service (DoS) Attacks QUESTIONS

1. Research a DoS Attack from the past 3 years. Record your findings in the table below.

|  |  |
| --- | --- |
| Outline of DoS Attack |  |
| Date(s) of attack: |  |
| What were the reasons (Financial, Political or Personal) for the DoS Attack? |  |
| What symptoms were experienced as a result of this DoS attack? |  |
| What effects did the DoS attack have on **users**? |  |
| What effects did the DoS attack have on the **business/ organisation** under attack? |  |
| What type of fault(s) did the DoS Attack create? |  |
| What costs were involved in the DoS Attack? |  |

## Topic 13 - Security Precautions

### Describe how encryption is used to secure transmission of data

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| **Definitions****Encryption**: Scrambling a message using a secret method (known as a cypher) so that only the sender and recipient (who know the cypher) can decode and read the message.**Cypher**: the process of encrypting a message |

#### Use of Public and Private keys

Data transmitted over the Internet is very easy to intercept and most of it is text based
In order to keep data secure in transit it is encrypted. A process, called a cypher, is used to scramble the data so that it doesn’t make sense. The cypher is reversible so the original message can be restored if you know the cypher.

Having both systems agreeing on a key that no one else knows becomes an issue. Both systems need to know what the key is without transmitting the key itself. Otherwise any one intercepting the encrypted message also knows the key. Public-key encryption (PKE) solves this problem by using 2 keys.

The two keys are mathematically linked, normally generated from a large, random number. The public key is known by everyone and is used to encrypt the message. The private key is known only by the recipient and is used to decrypt the message. The cyphers are very complex so that only the private key can decrypt the message. The public key cannot be used to work out the private key.

### Digital Certificates

Digital Certificates are the attachment to an electronic message used for security purposes.
It is used to verify that a user sending a message is who they claim to be and to bind their public key to them. Certificates can only be issued by certain trusted entities including Google, Symantec, and Comodo. The “lock” icon in your browser shows the status of the certificate. The lock indicates that the website is backed by a digital certificate and is a genuine website and is not a fake set up by criminals.

Digital Signatures

A digital signature is a way to ensure that an electronic message or document is authentic.
The signature is created when the message is sent, using a private encryption key
opposite to normal PKE. The signature is then paired with a public key and sent with the message. When the message run through the public key the result should match the signature. If they don’t match then the message has been altered en route, so the message has been intercepted and compromised.

## Security Precautions QUESTIONS

1. Explain, in your own words, how Public and Private Keys can keep data secure during transmission.

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1. Explain the purpose of Digital Certificates in keeping data secure.

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1. Explain the purpose of Digital Signatures in keeping data secure.

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1. https://www.ncsc.gov.uk/guidance/understanding-denial-service-dos-attacks [↑](#footnote-ref-1)