2b. Content of Computer systems (J277/01)

1.1 – Systems architecture

Sub topic	Guidance
1.1.1 Architecture of the CPU	
□ The purpose of the CPU: ○ The fetch-execute cycle □ Common CPU components and their function: ○ ALU (Arithmetic Logic Unit) ○ CU (Control Unit) ○ Cache ○ Registers □ Von Neumann architecture: ○ MAR (Memory Address Register) ○ MDR (Memory Data Register) ○ Program Counter ○ Accumulator	**Required** ✓ What actions occur at each stage of the fetch-execute cycle ✓ The role/purpose of each component and what it manages, stores, or controls during the fetch-execute cycle ✓ The purpose of each register, what it stores (data or address) ✓ The difference between storing data and an address **Not required** ✗ Knowledge of passing of data between registers in each stage
1.1.2 CPU performance	
□ How common characteristics of CPUs affect their performance: ○ Clock speed ○ Cache size ○ Number of cores	**Required** ✓ Understanding of each characteristic as listed ✓ The effects of changing any of the common characteristics on system performance, either individually or in combination
1.1.3 Embedded systems	
□ The purpose and characteristics of embedded systems □ Examples of embedded systems	**Required** ✓ What embedded systems are ✓ Typical characteristics of embedded systems ✓ Familiarity with a range of different embedded systems

1.2 – Memory and storage

Sub topic	Guidance
1.2.1 Primary storage (Memory)	
☐ The need for primary storage ☐ The difference between RAM and ROM ☐ The purpose of ROM in a computer system ☐ The purpose of RAM in a computer system ☐ Virtual memory	**Required** ✓ Why computers have primary storage ▪ How this usually consists of RAM and ROM ✓ Key characteristics of RAM and ROM ✓ Why virtual memory may be needed in a system ✓ How virtual memory works ▪ Transfer of data between RAM and HDD when RAM is filled
1.2.2 Secondary storage	
☐ The need for secondary storage ☐ Common types of storage: ○ Optical ○ Magnetic ○ Solid state ☐ Suitable storage devices and storage media for a given application ☐ The advantages and disadvantages of different storage devices and storage media relating to these characteristics: ○ Capacity ○ Speed ○ Portability ○ Durability ○ Reliability ○ Cost	**Required** ✓ Why computers have secondary storage ✓ Recognise a range of secondary storage devices/media ✓ Differences between each type of storage device/medium ✓ Compare advantages/disadvantages for each storage device ✓ Be able to apply their knowledge in context within scenarios **Not required** ✗ Understanding of the component parts of these types of storage

Sub topic	Guidance
1.2.3 Units	
□ The units of data storage: ○ Bit ○ Nibble (4 bits) ○ Byte (8 bits) ○ Kilobyte (1,000 bytes or 1 KB) ○ Megabyte (1,000 KB) ○ Gigabyte (1,000 MB) ○ Terabyte (1,000 GB) ○ Petabyte (1,000 TB) □ How data needs to be converted into a binary format to be processed by a computer □ Data capacity and calculation of data capacity requirements	**Required** ✓ Why data must be stored in binary format ✓ Familiarity with data units and moving between each ✓ Data storage devices have different fixed capacities ✓ Calculate required storage capacity for a given set of files ✓ Calculate file sizes of sound, images and text files ▪ sound file size = sample rate x duration (s) x bit depth ▪ image file size = colour depth x image height (px) x image width (px) ▪ text file size = bits per character x number of characters **Alternatives** • Use of 1,024 for conversions and calculations would be acceptable • Allowance for metadata in calculations may be used
1.2.4 Data storage	
Numbers □ How to convert positive denary whole numbers to binary numbers (up to and including 8 bits) and vice versa □ How to add two binary integers together (up to and including 8 bits) and explain overflow errors which may occur □ How to convert positive denary whole numbers into 2-digit hexadecimal numbers and vice versa □ How to convert binary integers to their hexadecimal equivalents and vice versa □ Binary shifts	**Required** ✓ Denary number range 0 – 255 ✓ Hexadecimal range 00 – FF ✓ Binary number range 00000000 – 11111111 ✓ Understanding of the terms 'most significant bit', and 'least significant bit' ✓ Conversion of any number in these ranges to another number base ✓ Ability to deal with binary numbers containing between 1 and 8 bits ▪ e.g. 11010 is the same as 00011010 ✓ Understand the effect of a binary shift (both left or right) on a number ✓ Carry out a binary shift (both left and right)

Sub topic	Guidance
Characters □ The use of binary codes to represent characters □ The term 'character set' □ The relationship between the number of bits per character in a character set, and the number of characters which can be represented, e.g.: ○ ASCII ○ Unicode	**Required** ✓ How characters are represented in binary ✓ How the number of characters stored is limited by the bits available ✓ The differences between and impact of each character set ✓ Understand how character sets are logically ordered, e.g. the code for 'B' will be one more than the code for 'A' ✓ Binary representation of ASCII in the exam will use 8 bits **Not required** ✗ Memorisation of character set codes
Images □ How an image is represented as a series of pixels, represented in binary □ Metadata □ The effect of colour depth and resolution on: ○ The quality of the image ○ The size of an image file	**Required** ✓ Each pixel has a specific colour, represented by a specific code ✓ The effect on image size and quality when changing colour depth and resolution ✓ Metadata stores additional image information (e.g. height, width, etc.)
Sound □ How sound can be sampled and stored in digital form □ The effect of sample rate, duration and bit depth on: ○ The playback quality ○ The size of a sound file	**Required** ✓ Analogue sounds must be stored in binary ✓ Sample rate – measured in Hertz (Hz) ✓ Duration – how many seconds of audio the sound file contains ✓ Bit depth – number of bits available to store each sample (e.g. 16-bit)
1.2.5 Compression	
□ The need for compression □ Types of compression: ○ Lossy ○ Lossless	**Required** ✓ Common scenarios where compression may be needed ✓ Advantages and disadvantages of each type of compression ✓ Effects on the file for each type of compression **Not required** ✗ Ability to carry out specific compression algorithms

1.3 – Computer networks, connections and protocols

Sub topic	Guidance
1.3.1 Networks and topologies	
□ Types of network: ○ LAN (Local Area Network) ○ WAN (Wide Area Network) □ Factors that affect the performance of networks □ The different roles of computers in a client-server and a peer-to-peer network □ The hardware needed to connect stand-alone computers into a Local Area Network: ○ Wireless access points ○ Routers ○ Switches ○ NIC (Network Interface Controller/Card) ○ Transmission media □ The Internet as a worldwide collection of computer networks: ○ DNS (Domain Name Server) ○ Hosting ○ The Cloud ○ Web servers and clients □ Star and Mesh network topologies	**Required** ✓ The characteristics of LANs and WANs including common examples of each ✓ Understanding of different factors that can affect the performance of a network, e.g.: ▪ Number of devices connected ▪ Bandwidth ✓ The tasks performed by each piece of hardware ✓ The concept of the Internet as a network of computer networks ✓ A Domain Name Service (DNS) is made up of multiple Domain Name Servers ✓ A DNS's role in the conversion of a URL to an IP address ✓ Concept of servers providing services (e.g. Web server → Web pages, File server → file storage/retrieval) ✓ Concept of clients requesting/using services from a server ✓ The Cloud: remote service provision (e.g. storage, software, processing) ✓ Advantages and disadvantages of the Cloud ✓ Advantages and disadvantages of the Star and Mesh topologies ✓ Apply understanding of networks to a given scenario

1.3.2 Wired and wireless networks, protocols and layers

□ Modes of connection:
- ○ Wired
  - Ethernet
- ○ Wireless
  - Wi-Fi
  - Bluetooth

□ Encryption

□ IP addressing and MAC addressing

□ Standards

□ Common protocols including:
- ○ TCP/IP (Transmission Control Protocol/Internet Protocol)
- ○ HTTP (Hyper Text Transfer Protocol)
- ○ HTTPS (Hyper Text Transfer Protocol Secure)
- ○ FTP (File Transfer Protocol)
- ○ POP (Post Office Protocol)
- ○ IMAP (Internet Message Access Protocol)
- ○ SMTP (Simple Mail Transfer Protocol)

□ The concept of layers

Required

✓ Compare benefits and drawbacks of wired versus wireless connection

✓ Recommend one or more connections for a given scenario

✓ The principle of encryption to secure data across network connections

✓ IP addressing and the format of an IP address (IPv4 and IPv6)

✓ A MAC address is assigned to devices; its use within a network

✓ The principle of a standard to provide rules for areas of computing

✓ Standards allows hardware/software to interact across different manufacturers/producers

✓ The principle of a (communication) protocol as a set of rules for transferring data

✓ That different types of protocols are used for different purposes

✓ The basic principles of each protocol i.e. its purpose and key features

✓ How layers are used in protocols, and the benefits of using layers; for a teaching example, please refer to the 4-layer TCP/IP model

Not required

✗ Understand how Ethernet, Wi-Fi and Bluetooth protocols work

✗ Understand differences between static and dynamic, or public and private IP addresses

✗ Knowledge of individual standards

✗ Knowledge of the names and function of each TCP/IP layer

1.4 – Network security

Sub topic	Guidance
1.4.1 Threats to computer systems and networks	
□ Forms of attack: ○ Malware ○ Social engineering, e.g. phishing, people as the ‘weak point’ ○ Brute-force attacks ○ Denial of service attacks ○ Data interception and theft ○ The concept of SQL injection	**Required** ✓ Threats posed to devices/systems ✓ Knowledge/principles of each form of attack including: ▪ How the attack is used ▪ The purpose of the attack
1.4.2 Identifying and preventing vulnerabilities	
□ Common prevention methods: ○ Penetration testing ○ Anti-malware software ○ Firewalls ○ User access levels ○ Passwords ○ Encryption ○ Physical security	**Required** ✓ Understanding of how to limit the threats posed in 1.4.1 ✓ Understanding of methods to remove vulnerabilities ✓ Knowledge/principles of each prevention method: ▪ What each prevention method may limit/prevent ▪ How it limits the attack

1.5 – Systems software

Sub topic	Guidance
1.5.1 Operating systems	
□ The purpose and functionality of operating systems: ○ User interface ○ Memory management and multitasking ○ Peripheral management and drivers ○ User management ○ File management	**Required** ✓ What each function of an operating system does ✓ Features of a user interface ✓ Memory management, e.g. the transfer of data between memory, and how this allows for multitasking ✓ Understand that: ▪ Data is transferred between devices and the processor ▪ This process needs to be managed ✓ User management functions, e.g.: ▪ Allocation of an account ▪ Access rights ▪ Security, etc. ✓ File management, and the key features, e.g.: ▪ Naming ▪ Allocating to folders ▪ Moving files ▪ Saving, etc. **Not required** ✗ Understanding of paging or segmentation
1.5.2 Utility software	
□ The purpose and functionality of utility software □ Utility system software: ○ Encryption software ○ Defragmentation ○ Data compression	**Required** ✓ Understand that computers often come with utility software, and how this performs housekeeping tasks ✓ Purpose of the identified utility software and why it is required

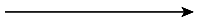
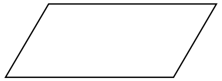
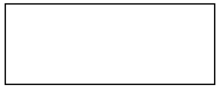
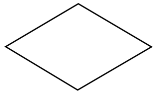
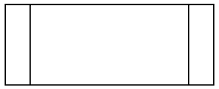
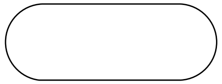
1.6 – Ethical, legal, cultural and environmental impacts of digital technology	
Sub topic	**Guidance**
1.6.1 Ethical, legal, cultural and environmental impact	
□ Impacts of digital technology on wider society including: ○ Ethical issues ○ Legal issues ○ Cultural issues ○ Environmental issues ○ Privacy issues □ Legislation relevant to Computer Science: ○ The Data Protection Act 2018 ○ Computer Misuse Act 1990 ○ Copyright Designs and Patents Act 1988 ○ Software licences (i.e. open source and proprietary)	**Required** ✓ Technology introduces ethical, legal, cultural, environmental and privacy issues ✓ Knowledge of a variety of examples of digital technology and how this impacts on society ✓ An ability to discuss the impact of technology based around the issues listed ✓ The purpose of each piece of legislation and the specific actions it allows or prohibits ✓ The need to license software and the purpose of a software licence ✓ Features of open source (providing access to the source code and the ability to change the software) ✓ Features of proprietary (no access to the source code, purchased commonly as off-the-shelf) ✓ Recommend a type of licence for a given scenario including benefits and drawbacks

2c. Content of Computational thinking, algorithms and programming (J277/02)

2.1 – Algorithms

Sub topic	Guidance
2.1.1 Computational thinking	
□ Principles of computational thinking: ○ Abstraction ○ Decomposition ○ Algorithmic thinking	**Required** ✓ Understanding of these principles and how they are used to define and refine problems
2.1.2 Designing, creating and refining algorithms	
□ Identify the inputs, processes, and outputs for a problem □ Structure diagrams □ Create, interpret, correct, complete, and refine algorithms using: ○ Pseudocode ○ Flowcharts ○ Reference language/high-level programming language □ Identify common errors □ Trace tables	**Required** ✓ Produce simple diagrams to show: ▪ The structure of a problem ▪ Subsections and their links to other subsections ✓ Complete, write or refine an algorithm using the techniques listed ✓ Identify syntax/logic errors in code and suggest fixes ✓ Create and use trace tables to follow an algorithm

Flowchart symbols

	**Line**		**Input/ Output**
	**Process**		**Decision**
	**Sub program**		**Terminal**

2.1.3 Searching and sorting algorithms

□ Standard searching algorithms:

- ○ Binary search
- ○ Linear search

□ Standard sorting algorithms:

- ○ Bubble sort
- ○ Merge sort
- ○ Insertion sort

Required

- ✓ Understand the main steps of each algorithm
- ✓ Understand any pre-requisites of an algorithm
- ✓ Apply the algorithm to a data set
- ✓ Identify an algorithm if given the code or pseudocode for it

Not required

- ✗ To remember the code for these algorithms
- ✗ To remember Exam Reference Language for Merge Sort

2.2 – Programming fundamentals

Sub topic	Guidance
2.2.1 Programming fundamentals	

Sub topic

- ☐ The use of variables, constants, operators, inputs, outputs and assignments
- ☐ The use of the three basic programming constructs used to control the flow of a program:
  - ○ Sequence
  - ○ Selection
  - ○ Iteration (count- and condition-controlled loops)
- ☐ The common arithmetic operators
- ☐ The common Boolean operators AND, OR and NOT

Guidance

Required

- ✓ Practical use of the techniques in a high-level language within the classroom
- ✓ Understanding of each technique
- ✓ Recognise and use the following operators:

Comparison operators		Arithmetic operators	
==	Equal to	+	Addition
!=	Not equal to	–	Subtraction
<	Less than	*	Multiplication
<=	Less than or equal to	/	Division
>	Greater than	MOD	Modulus
>=	Greater than or equal to	DIV	Quotient
		^	Exponentiation (to the power)

2.2.2 Data types	
□ The use of data types: ○ Integer ○ Real ○ Boolean ○ Character and string ○ Casting	**Required** ✓ Practical use of the data types in a high-level language within the classroom ✓ Ability to choose suitable data types for data in a given scenario ✓ Understand that data types may be temporarily changed through casting, and where this may be useful
2.2.3 Additional programming techniques	
□ The use of basic string manipulation □ The use of basic file handling operations: ○ Open ○ Read ○ Write ○ Close □ The use of records to store data □ The use of SQL to search for data □ The use of arrays (or equivalent) when solving problems, including both one-dimensional (1D) and two-dimensional arrays (2D) □ How to use sub programs (functions and procedures) to produce structured code □ Random number generation	**Required** ✓ Practical use of the additional programming techniques in a high-level language within the classroom ✓ Ability to manipulate strings, including: ▪ Concatenation ▪ Slicing ✓ Arrays as fixed length or static structures ✓ Use of 2D arrays to emulate database tables of a collection of fields, and records ✓ The use of functions ✓ The use of procedures ✓ Where to use functions and procedures effectively ✓ The use of the following within functions and procedures: ▪ local variables/constants ▪ global variables/constants ▪ arrays (passing and returning) ✓ SQL commands: ▪ SELECT ▪ FROM ▪ WHERE ✓ Be able to create and use random numbers in a program

2.3 – Producing robust programs

Sub topic	Guidance
2.3.1 Defensive design	
□ Defensive design considerations: ○ Anticipating misuse ○ Authentication □ Input validation □ Maintainability: ○ Use of sub programs ○ Naming conventions ○ Indentation ○ Commenting	**Required** ✓ Understanding of the issues a programmer should consider to ensure that a program caters for all likely input values ✓ Understanding of how to deal with invalid data in a program ✓ Authentication to confirm the identity of a user ✓ Practical experience of designing input validation and simple authentication (e.g. username and password) ✓ Understand why commenting is useful and apply this appropriately
2.3.2 Testing	
□ The purpose of testing □ Types of testing: ○ Iterative ○ Final/terminal □ Identify syntax and logic errors □ Selecting and using suitable test data: ○ Normal ○ Boundary ○ Invalid/Erroneous □ Refining algorithms	**Required** ✓ The difference between testing modules of a program during development and testing the program at the end of production ✓ Syntax errors as errors which break the grammatical rules of the programming language and stop it from being run/translated ✓ Logic errors as errors which produce unexpected output ✓ Normal test data as data which should be accepted by a program without causing errors ✓ Boundary test data as data of the correct type which is on the very edge of being valid ✓ Invalid test data as data of the correct data type which should be rejected by a computer system ✓ Erroneous test data as data of the incorrect data type which should be rejected by a computer system ✓ Ability to identify suitable test data for a given scenario ✓ Ability to create/complete a test plan

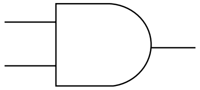
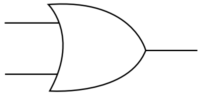
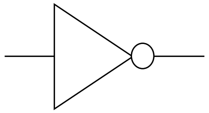
2.4 – Boolean logic

Sub topic	Guidance
2.4.1 Boolean logic	

- □ Simple logic diagrams using the operators AND, OR and NOT
- □ Truth tables
- □ Combining Boolean operators using AND, OR and NOT
- □ Applying logical operators in truth tables to solve problems

Required

- ✓ Knowledge of the truth tables for each logic gate
- ✓ Recognition of each gate symbol
- ✓ Understanding of how to create, complete or edit logic diagrams and truth tables for given scenarios
- ✓ Ability to work with more than one gate in a logic diagram

Boolean Operators	Logic Gate Symbol
AND *(Conjunction)*	
OR *(Disjunction)*	
NOT *(Negation)*	

Truth Tables

AND			OR			NOT	
A	B	A AND B	A	B	A OR B	A	NOT A
0	0	0	0	0	0	0	1
0	1	0	0	1	1	1	0
1	0	0	1	0	1		
1	1	1	1	1	1		

Alternatives

- Use of other valid notation will be accepted within the examination, e.g. Using T/F for 1/0, or V for OR, etc.

2.5 – Programming languages and Integrated Development Environments

Sub topic	Guidance
2.5.1 Languages	
□ Characteristics and purpose of different levels of programming language: ○ High-level languages ○ Low-level languages □ The purpose of translators □ The characteristics of a compiler and an interpreter	**Required** ✓ The differences between high- and low-level programming languages ✓ The need for translators ✓ The differences, benefits and drawbacks of using a compiler or an interpreter **Not required** ✗ Understanding of assemblers
2.5.2 The Integrated Development Environment (IDE)	
□ Common tools and facilities available in an Integrated Development Environment (IDE): ○ Editors ○ Error diagnostics ○ Run-time environment ○ Translators	**Required** ✓ Knowledge of the tools that an IDE provides ✓ How each of the tools and facilities listed can be used to help a programmer develop a program ✓ Practical experience of using a range of these tools within at least one IDE