# 3 Subject content

This syllabus gives you the flexibility to design a course that will interest, challenge and engage your learners. Where appropriate you are responsible for selecting resources and examples to support your learners' study. These should be appropriate for the learners' age, cultural background and learning context as well as complying with your school policies and local legal requirements.

## AS content

Computational thinking is developed using a structured approach that includes the use of programming and problem-solving skills to provide solutions to real life problems. It requires the manipulation and storage of different types of data and the communication of solutions over networks.

Computational thinking is supported by developing an understanding of how computer architecture, hardware, systems software, security measures and communication systems, provide the infrastructure required in an efficient and ethical way. The syllabus supports opportunities for students to apply their skills in practical contexts that are required in the digital industry.

### 1 Information representation

### 1.1 Data Representation

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of binary magnitudes and the difference between binary prefixes and decimal prefixes | Understand the difference between and use:<br>• kibi and kilo<br>• mebi and mega<br>• gibi and giga<br>• tebi and tera |
| Show understanding of different number systems | Use the binary, denary, hexadecimal number bases and Binary Coded Decimal (BCD) and one's and two's complement representation for binary numbers<br>Convert an integer value from one number base/ representation to another |
| Perform binary addition and subtraction | Using positive and negative binary integers<br>Show understanding of how overflow can occur |
| Describe practical applications where Binary Coded Decimal (BCD) and Hexadecimal are used | |
| Show understanding of and be able to represent character data in its internal binary form, depending on the character set used | Students are expected to be familiar with ASCII (American Standard Code for Information Interchange), extended ASCII and Unicode. Students will not be expected to memorise any particular character codes |

## 1.2 Multimedia

### Graphics

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of how data for a bitmapped image are encoded | Use and understand the terms: pixel, file header, image resolution, screen resolution, colour depth/ bit depth |
| Perform calculations to estimate the file size for a bitmap image | |
| Show understanding of the effects of changing elements of a bitmap image on the image quality and file size | Use the terms: image resolution, colour depth / bit depth |
| Show understanding of how data for a vector graphic are encoded | Use the terms: drawing object, property, drawing list |
| Justify the use of a bitmap image or a vector graphic for a given task | |

### Sound

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of how sound is represented and encoded | Use the terms: sampling, sampling rate, sampling resolution, analogue and digital data |
| Show understanding of the impact of changing the sampling rate and resolution | Including the impact on file size and accuracy |

## 1.3 Compression

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the need for and examples of the use of compression | |
| Show understanding of lossy and lossless compression and justify the use of a method in a given situation | |
| Show understanding of how a text file, bitmap image, vector graphic and sound file can be compressed | Including the use of run-length encoding (RLE) |

## 2 Communication

### 2.1 Networks including the internet

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the purpose and benefits of networking devices | |
| Show understanding of the characteristics of a LAN (local area network) and a WAN (wide area network) | |
| Explain the client-server and peer-to-peer models of networked computers | Roles of the different computers within the network and subnetwork models<br>Benefits and drawbacks of each model<br>Justify the use of a model for a given situation |
| Show understanding of thin-client and thick-client and the differences between them | |
| Show understanding of the bus, star, mesh and hybrid topologies | Understand how packets are transmitted between two hosts for a given topology<br>Justify the use of a topology for a given situation |
| Show understanding of cloud computing | Including the use of public and private clouds<br>Benefits and drawbacks of cloud computing |
| Show understanding of the differences between and implications of the use of wireless and wired networks | Describe the characteristics of copper cable, fibre-optic cable, radio waves (including WiFi), microwaves, satellites |
| Describe the hardware that is used to support a LAN | Including switch, server, Network Interface Card (NIC), Wireless Network Interface Card (WNIC), Wireless Access Points (WAP), cables, bridge, repeater |
| Describe the role and function of a router in a network | |
| Show understanding of Ethernet and how collisions are detected and avoided | Including Carrier Sense Multiple Access/Collision Detection (CSMA/CD) |
| Show understanding of bit streaming | Methods of bit streaming, i.e. real-time and on-demand<br>Importance of bit rates broadband speed on bit streaming |
| Show understanding of the differences between the World Wide Web (WWW) and the internet | |
| Describe the hardware that is used to support the internet | Including modems, PSTN (Public Switched Telephone Network), dedicated lines, cell phone network |

## 2.1 Networks including the internet continued

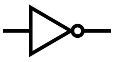
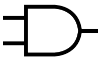
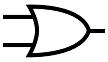
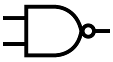
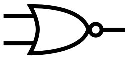
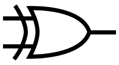
| | |
|---|---|
| Explain the use of IP addresses in the transmission of data over the internet | Including:<br>• format of an IP address including IPv4 and IPv6<br>• use of subnetting in a network<br>• how an IP address is associated with a device on a network<br>• difference between a public IP address and a private IP address and the implications for security<br>• difference between a static IP address and a dynamic IP address |
| Explain how a Uniform Resource Locator (URL) is used to locate a resource on the World Wide Web (WWW) and the role of the Domain Name Service (DNS) | |

## 3 Hardware

### 3.1 Computers and their components

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the need for input, output, primary memory and secondary (including removable) storage | |
| Show understanding of embedded systems | Including: benefits and drawbacks of embedded systems |
| Describe the principal operations of hardware devices | Including: Laser printer, 3D printer, microphone, speakers, magnetic hard disk, solid state (flash) memory, optical disc reader/writer, touchscreen, virtual reality headset |
| Show understanding of the use of buffers | |
| Explain the differences between Random Access Memory (RAM) and Read Only Memory (ROM) | Including their use in a range of devices and systems |
| Explain the differences between Static RAM (SRAM) and Dynamic RAM (DRAM) | Including the use of SRAM and DRAM in a range of devices and systems and the reasons for using one instead of the other depending on the device and its use |
| Explain the difference between Programmable ROM (PROM), Erasable Programmable ROM (EPROM) and Electrically Erasable Programmable ROM (EEPROM) | |
| Show an understanding of monitoring and control systems | Including:<br>• difference between monitoring and control<br>• use of sensors (including temperature, pressure, infra-red, sound) and actuators<br>• importance of feedback |

## 3.2 Logic Gates and Logic Circuits

| Candidates should be able to: | Notes and guidance |
|---|---|
| Use the following logic gate symbols:<br> NOT<br> AND<br> OR<br> NAND<br> NOR<br> XOR | |
| Understand and define the functions of :<br>NOT, AND, OR, NAND, NOR and XOR (EOR) gates | All gates except the NOT gate will have two inputs only. |
| Construct the truth table for each of the logic gates above | |
| Construct a logic circuit | From:<br>• a problem statement<br>• a logic expression<br>• a truth table |
| Construct a truth table | From:<br>• a problem statement<br>• a logic circuit<br>• a logic expression |
| Construct a logic expression | From:<br>• a problem statement<br>• a logic circuit<br>• a truth table |

## 4 Processor Fundamentals

### 4.1 Central Processing Unit (CPU) Architecture

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the basic Von Neumann model for a computer system and the stored program concept | |
| Show understanding of the purpose and role of registers, including the difference between general purpose and special purpose registers | Special purpose registers including:<br>• Program Counter (PC)<br>• Memory Data Register (MDR)<br>• Memory Address Register (MAR)<br>• The Accumulator (ACC)<br>• Index Register (IX)<br>• Current Instruction Register (CIR)<br>• Status Register |
| Show understanding of the purpose and roles of the Arithmetic and Logic Unit (ALU), Control Unit (CU) and system clock, Immediate Access Store (IAS) | |
| Show understanding of how data are transferred between various components of the computer system using the address bus, data bus and control bus | |
| Show understanding of how factors contribute to the performance of the computer system | Including:<br>• processor type and number of cores<br>• the bus width<br>• clock speed<br>• cache memory |
| Understand how different ports provide connection to peripheral devices | Including connection to:<br>• Universal Serial Bus (USB)<br>• High Definition Multimedia Interface (HDMI)<br>• Video Graphics Array (VGA) |
| Describe the stages of the Fetch-Execute (F-E) cycle | Describe and use ‘register transfer’ notation to describe the F-E cycle |
| Show understanding of the purpose of interrupts | Including:<br>• possible causes of interrupts<br>• applications of interrupts<br>• use of an Interrupt Service handling Routine (ISR)<br>• when interrupts are detected during the fetch-execute cycle<br>• how interrupts are handled |

## 4.2 Assembly Language

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the relationship between assembly language and machine code | |
| Describe the different stages of the assembly process for a two-pass assembler | Apply the two-pass assembler process to a given simple assembly language program |
| Trace a given simple assembly language program | |
| Show understanding that a set of instructions are grouped | Including the following groups:<br>• Data movement<br>• Input and output of data<br>• Arithmetic operations<br>• Unconditional and conditional instructions<br>• Compare instructions |
| Show understanding of and be able to use different modes of addressing | Including immediate, direct, indirect, indexed, relative |

The following table is an example of an instruction set:

| Instruction | | Explanation |
|---|---|---|
| **Opcode** | **Operand** | |
| `LDM` | `#n` | Immediate addressing. Load the number n to ACC |
| `LDD` | `<address>` | Direct addressing. Load the contents of the location at the given address to ACC |
| `LDI` | `<address>` | Indirect addressing. The address to be used is at the given address. Load the contents of this second address to ACC |
| `LDX` | `<address>` | Indexed addressing. Form the address from <address> + the contents of the index register. Copy the contents of this calculated address to ACC |
| `LDR` | `#n` | Immediate addressing. Load the number n to IX |
| `MOV` | `<register>` | Move the contents of the accumulator to the given register (IX) |
| `STO` | `<address>` | Store the contents of ACC at the given address |
| `ADD` | `<address>` | Add the contents of the given address to the ACC |
| `ADD` | `#n/Bn/&n` | Add the number n to the ACC |
| `SUB` | `<address>` | Subtract the contents of the given address from the ACC |
| `SUB` | `#n/Bn/&n` | Subtract the number n from the ACC |
| `INC` | `<register>` | Add 1 to the contents of the register (ACC or IX) |
| `DEC` | `<register>` | Subtract 1 from the contents of the register (ACC or IX) |
| `JMP` | `<address>` | Jump to the given address |
| `CMP` | `<address>` | Compare the contents of ACC with the contents of <address> |
| `CMP` | `#n` | Compare the contents of ACC with number n |
| `CMI` | `<address>` | Indirect addressing. The address to be used is at the given address. Compare the contents of ACC with the contents of this second address |
| `JPE` | `<address>` | Following a compare instruction, jump to <address> if the compare was True |
| `JPN` | `<address>` | Following a compare instruction, jump to <address> if the compare was False |
| `IN` | | Key in a character and store its ASCII value in ACC |
| `OUT` | | Output to the screen the character whose ASCII value is stored in ACC |
| `END` | | Return control to the operating system |
| All questions will assume there is only one general purpose register available (Accumulator)<br>ACC denotes Accumulator<br>IX denotes Index Register<br><address> can be an absolute or symbolic address<br># denotes a denary number, e.g. #123<br>B denotes a binary number, e.g. B01001010<br>& denotes a hexadecimal number, e.g. &4A | | |

## 4.3 Bit manipulation

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of and perform binary shifts | Logical, arithmetic and cyclic<br>Left shift, right shift |
| Show understanding of how bit manipulation can be used to monitor/control a device | Carry out bit manipulation operations<br>Test and set a bit (using bit masking) |

| | Instruction | | |
|---|---|---|---|
| Label | Opcode | Operand | Explanation |
| | `AND` | `#n / Bn / &n` | Bitwise AND operation of the contents of ACC with the operand |
| | `AND` | `<address>` | Bitwise AND operation of the contents of ACC with the contents of <address> |
| | `XOR` | `#n / Bn / &n` | Bitwise XOR operation of the contents of ACC with the operand |
| | `XOR` | `<address>` | Bitwise XOR operation of the contents of ACC with the contents of <address> |
| | `OR` | `#n / Bn / &n` | Bitwise OR operation of the contents of ACC with the operand |
| | `OR` | `<address>` | Bitwise OR operation of the contents of ACC with the contents of <address> |
| | `LSL` | `#n` | Bits in ACC are shifted logically n places to the left. Zeros are introduced on the right hand end |
| | `LSR` | `#n` | Bits in ACC are shifted logically n places to the right. Zeros are introduced on the left hand end |
| `<label>:` | `<opcode>` | `<operand>` | Labels an instruction |
| `<label>:` | | `<data>` | Gives a symbolic address <label> to the memory location with contents <data> |

All questions will assume there is only one general purpose register available (Accumulator)
ACC denotes Accumulator
IX denotes Index Register
<address> can be an absolute or symbolic address
# denotes a denary number, e.g. #123
B denotes a binary number, e.g. B01001010
& denotes a hexadecimal number, e.g. &4A

## 5 System Software

### 5.1 Operating Systems

| Candidates should be able to: | Notes and guidance |
|---|---|
| Explain why a computer system requires an Operating System (OS) | |
| Explain the key management tasks carried out by the Operating System | Including memory management, file management, security management, hardware management (input / output / peripherals), process management |
| Show understanding of the need for typical utility software provided with an Operating System | Including disk formatter, virus checker, defragmentation software, disk contents analysis/ disk repair software, file compression, back-up software |
| Show understanding of program libraries | Including:<br>• software under development is often constructed using existing code from program libraries<br>• the benefits to the developer of software constructed using library files, including Dynamic Link Library (DLL) files |

### 5.2 Language Translators

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the need for:<br>• assembler software for the translation of an assembly language program<br>• a compiler for the translation of a high-level language program<br>• an interpreter for translation and execution of a high-level language program | |
| Explain the benefits and drawbacks of using either a compiler or interpreter and justify the use of each | |
| Show awareness that high-level language programs may be partially compiled and partially interpreted, such as Java (console mode) | |
| Describe features found in a typical Integrated Development Environment (IDE) | Including:<br>• for coding, including context-sensitive prompts<br>• for initial error detection, including dynamic syntax checks<br>• for presentation, including prettyprint, expand and collapse code blocks<br>• for debugging, including single stepping, breakpoints, i.e. variables, expressions, report window |

## 6 Security, privacy and data integrity

### 6.1 Data Security

| Candidates should be able to: | Notes and guidance |
|---|---|
| Explain the difference between the terms security, privacy and integrity of data | |
| Show appreciation of the need for both the security of data and the security of the computer system | |
| Describe security measures designed to protect computer systems, ranging from the stand-alone PC to a network of computers | Including user accounts, passwords, authentication techniques such as digital signatures and biometrics, firewall, anti-virus software, anti-spyware, encryption |
| Show understanding of the threats to computer and data security posed by networks and the internet | Including malware (virus, spyware), hackers, phishing, pharming |
| Describe methods that can be used to restrict the risks posed by threats | |
| Describe security methods designed to protect the security of data | Including encryption, access rights |

### 6.2 Data Integrity

| Candidates should be able to: | Notes and guidance |
|---|---|
| Describe how data validation and data verification help protect the integrity of data | |
| Describe and use methods of data validation | Including range check, format check, length check, presence check, existence check, limit check, check digit |
| Describe and use methods of data verification during data entry and data transfer | During data entry including visual check, double entry<br>During data transfer including parity check (byte and block), checksum |

## 7 Ethics and Ownership

### 7.1 Ethics and Ownership

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the need for and purpose of ethics as a computing professional | Understand the importance of joining a professional ethical body including BCS (British Computer Society), IEEE (Institute of Electrical and Electronic Engineers) |
| Show understanding of the need to act ethically and the impact of acting ethically or unethically for a given situation | |
| Show understanding of the need for copyright legislation | |
| Show understanding of the different types of software licencing and justify the use of a licence for a given situation | Licences to include free Software Foundation, the Open Source Initiative, shareware and commercial software |
| Show understanding of Artificial Intelligence (AI) | Understand the impact of AI including social, economic and environmental issues<br>Understand the applications of AI |

## 8 Databases

### 8.1 Database Concepts

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the limitations of using a file-based approach for the storage and retrieval of data | |
| Describe the features of a relational database that address the limitations of a file-based approach | |
| Show understanding of and use the terminology associated with a relational database model | Including entity, table, record, field, tuple, attribute, primary key, candidate key, secondary key, foreign key, relationship (one-to-many, one-to-one, many-to-many), referential integrity, indexing |
| Use an entity-relationship (E-R) diagram to document a database design | |
| Show understanding of the normalisation process | First Normal Form (1NF),<br>Second Normal Form (2NF) and<br>Third Normal Form (3NF) |
| Explain why a given set of database tables are, or are not, in 3NF | |
| Produce a normalised database design for a description of a database, a given set of data, or a given set of tables | |

## 8.2 Database Management Systems (DBMS)

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding of the features provided by a Database Management System (DBMS) that address the issues of a file based approach | Including:<br>• data management, including maintaining a data dictionary<br>• data modelling<br>• logical schema<br>• data integrity<br>• data security, including backup procedures and the use of access rights to individuals / groups of users |
| Show understanding of how software tools found within a DBMS are used in practice | Including the use and purpose of:<br>• developer interface<br>• query processor |

## 8.3 Data Definition Language (DDL) and Data Manipulation Language (DML)

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding that the DBMS carries out all creation / modification of the database structure using its Data Definition Language (DDL) | |
| Show understanding that the DBMS carries out all queries and maintenance of data using its DML | |
| Show understanding that the industry standard for both DDL and DML is Structured Query Language (SQL) | Understand a given SQL statement |
| Understand given SQL (DDL) statements and be able to write simple SQL (DDL) statements using a sub-set of statements | Create a database (CREATE DATABASE)<br>Create a table definition (CREATE TABLE), including the creation of attributes with appropriate data types:<br>• CHARACTER<br>• VARCHAR(n)<br>• BOOLEAN<br>• INTEGER<br>• REAL<br>• DATE<br>• TIME<br>change a table definition (ALTER TABLE)<br>add a primary key to a table (PRIMARY KEY (field))<br>add a foreign key to a table (FOREIGN KEY (field) REFERENCES Table (Field)) |

### 8.3 Data Definition Language (DDL) and Data Manipulation Language (DML) continued

| | |
|---|---|
| Write an SQL script to query or modify data (DML) which are stored in (at most two) database tables | Queries including SELECT... FROM, WHERE, ORDER BY, GROUP BY, INNER JOIN, SUM, COUNT, AVG<br>Data maintenance including. INSERT INTO, DELETE FROM, UPDATE |

## 9 Algorithm Design and Problem-solving

Refer to Pseudocode Guide **www.cambridgeinternational.org/support**

### 9.1 Computational Thinking Skills

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show an understanding of abstraction | Need for and benefits of using abstraction<br>Describe the purpose of abstraction<br>Produce an abstract model of a system by only including essential details |
| Describe and use decomposition | Break down problems into sub-problems leading to the concept of a program module (procedure / function) |

### 9.2 Algorithms

| Candidates should be able to: | Notes and guidance |
|---|---|
| Show understanding that an algorithm is a solution to a problem expressed as a sequence of defined steps | |
| Use suitable identifier names for the representation of data used by a problem and represent these using an identifier table | |
| Write pseudocode that contains input, process and output | |
| Write pseudocode using the three basic constructs of sequence, selection and iteration (repetition) | |
| Document a simple algorithm using a structured English description, a flowchart or pseudocode | |
| Write pseudocode from:<br>• a structured English description<br>• a flowchart | |
| Draw a flowchart from:<br>• a structured English description<br>• pseudocode | |