0 1 . 1 Describe the difference between analogue and digital data.

[2 marks]

Two methods of representing music digitally are as sampled sound and using MIDI.

0 1 . 2 State **two** advantages of representing music using MIDI instead of as sampled sound.

[2 marks]

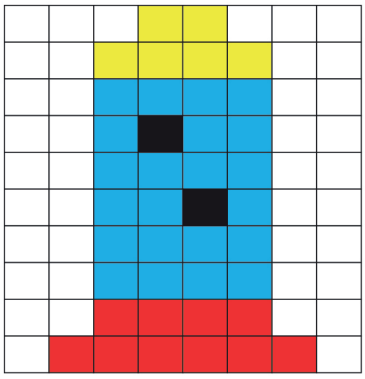
0 2 . 1 Cameras within the taxi take still images once every second for security purposes. The images are compressed using run-length encoding and stored on a flash memory card within the camera.

Describe how a digital image could be captured by a digital camera and compressed using run-length encoding.

[6 marks]

0 3 **Figure 5** shows a bitmap representation of an image consisting of white, red, blue, black and yellow pixels only.

Figure 5



0 3 . 1 Calculate the minimum size of file (excluding metadata) that could be used to store the bitmap image in **Figure 5**. Express your answer in bytes.

You **must** show your working.

[3 marks]

0 3 . 2 Shade in **one** lozenge to indicate the minimum colour depth in bits required for an image with 18 colours.

[1 mark]

3 ⬭ **4** ⬭ **5** ⬭

0 4 . 1 Sampling with an 8-bit sample resolution means that each sample can be approximated to one of 256 different levels.

If the sample resolution is increased to 10 bits, how many **more** levels are available for approximating samples?

[1 mark]

0 4 . 2 A sound lasts 3 minutes and 20 seconds. It is sampled at a 44.1kHz sample rate with a 16-bit sample resolution.

A sample rate of 1Hz means that one sample has been taken every second.

Calculate the minimum amount of storage space, in megabytes (MB), needed to store the sampled sound.

You should show your working.

[3 marks]

Answer:

0 5 . 1 A sound is being recorded from an analogue source using a sound card in a computer. The sound card contains an analogue to digital converter (ADC).

Describe the steps the ADC performs in this process.

[3 marks]

A sound has been recorded and takes up 34.56 megabytes (MB) of storage space.
The sound lasts 360 seconds and was recorded with a sample resolution of 16 bits.

0 5 . 2 Calculate the sample rate used for the recording.

State your answer in samples per second (Hertz).

You should show your working.

[2 marks]

Answer _____

0 5 . 3 State Nyquist's theorem.

[2 marks]

0 6 A student has attempted to calculate the minimum file size, in bytes, of a bitmapped image.

The bitmapped image is 10 pixels wide by 16 pixels high with 4 possible colours for each pixel.

The student calculates the answer to be 80 bytes by using the following method:

$$\frac{\text{number of pixels wide} \times \text{number of pixels high} \times \text{number of colours}}{\text{number of bits in a byte}}$$

Explain what the student has done wrong **and** state the correct minimum file size in bytes.

[2 marks]

What the student has done wrong _____

_____

_____

_____

Correct minimum file size _____

_____

0 7 . 1 Write an assembly language program to encrypt a single character using the Caesar cipher. The character to be encrypted is represented using a character set consisting of 26 characters with character codes 0–25. The output of the process should be the character code of the encrypted character.

The assembly language instruction set that you should use to write the program is listed in **Table 1**.

Table 2 shows the character codes and the characters they represent.

Table 2

Code	Character
0	A
1	B
2	C
3	D
4	E
5	F
6	G
7	H
8	I

Code	Character
9	J
10	K
11	L
12	M
13	N
14	O
15	P
16	Q
17	R

Code	Character
18	S
19	T
20	U
21	V
22	W
23	X
24	Y
25	Z

- Memory location 100 contains the character code to be encrypted, which is in the range 0–25
- Memory location 101 contains an integer key to be used for encryption, which is in the range 0–25
- The program should store the character code of the encrypted character in memory location 102

[4 marks]

0 7 . 2 Another method of encryption is the Vernam cipher.

Explain why, under the correct conditions, the Vernam cipher is perfectly secure.

[1 mark]

0 8 . 1 State **one** reason why a user might choose to compress an image file.

[1 mark]

0 8 . 2 Describe **one** advantage of lossless compression over lossy compression.

[1 mark]

0 8 . 3 Explain how data can be compressed using dictionary-based compression.

[3 marks]

0 9 . 1 Describe the difference between analogue and digital data.

[2 marks]

0 9 . 2 Describe the steps that an analogue to digital converter (ADC) carries out when converting a sound signal.

[3 marks]

1 0 An international technology company produces a smart speaker for use in homes. The smart speaker can be controlled by a user providing voice commands, which means the device must always be listening for audio input. The company stores audio recordings of each user to analyse when improving its voice recognition algorithms. The audio recordings are compressed using lossy compression and then sent over the Internet to be stored at the company's headquarters.

Discuss a range of ethical, legal and cultural issues that are raised by the company storing the audio captured by its smart speakers **and** justify why the company might use lossy compression.

You will be assessed on your ability to follow a line of reasoning to produce a coherent, relevant and structured response.

[12 marks]

1 1 . 1 Describe how to calculate the minimum storage requirements, excluding metadata, of a bitmapped image.

[1 mark]

One way of representing sound digitally is by using sampling.

1 1 . 2 What is meant by the term **sampling rate**?

[1 mark]

1 1 . 3 What is meant by the term **sample resolution**?

[1 mark]

1 1 . 4 A sampled sound could be compressed using lossy compression.

Describe a problem that may occur if lossy compression is used and how the compression method has caused this.

[2 marks]

1 1 . 5 An alternative to using sampled sound is MIDI.

State **two** advantages of using MIDI instead of sampled sound.

[2 marks]

1 2 A clothing company has developed an application that allows a user to take a photograph of themself on their mobile phone and upload it to their account on the company servers. The application will then use artificial intelligence to recommend new clothes that it computes will suit the user based on their preferences and the application's own interpretation of the way they look. It will then generate images of the user wearing the recommended clothes.

The user can preview the images and either buy the clothes from the company or use the generated images by linking to them from social media accounts.

Describe how a digital camera would work when capturing a photograph of the user for the application **and** discuss the moral, ethical, legal and cultural issues that developers of the application may have had to consider while developing it.

[9 marks]

1 3 . 1 State the name of the component on a sound card that transforms the continuous signal received from a microphone to a form that can be stored by a computer.

[1 mark]

1 3 . 2 A bitmap image is 52 pixels in height and 26 pixels in width. The bitmap representation of the image requires 845 bytes.

Calculate the maximum number of colours that could be used in the bitmap image.

You should show all your working.

[2 marks]

1 3 . 3 When a bitmap image is stored in a file, additional information is stored as well as the colours of the pixels. For example, the bitmap file might contain information on the date of creation, image width and height.

State the name given to this additional information when storing a bitmap image.

[1 mark]

1 3 . 4 A sound is recorded with a sample rate of 96 000 Hz and a sample resolution of 24 bits. The file size of the recording is 12 096 kilobytes.

A sample rate of 1 Hz means that one sample has been taken every second.

Calculate the duration of the sound recording.

You should show all your working.

[3 marks]

1 3 . 5 A sample resolution of 16 bits is commonly used in audio recordings.

Explain why increasing the sample resolution from 16 bits to 24 bits can improve the quality of an audio recording.

[1 mark]

1 3 . 6 MIDI does not use sampling to represent music.

Describe how music is represented using MIDI.

[2 marks]

1 3 . 7 Explain **one** advantage of using MIDI instead of sampled sound to represent music.

[1 mark]

1 4 . 1 A message is encrypted using a Caesar cipher that operates with a shift value of four. For example, the letter A in plaintext would be represented by E in ciphertext.

The ciphertext for the message is `WSSDI`.

What is the plaintext for the message?

[1 mark]

1 4 . 2 Explain **two** reasons why Caesar ciphers are vulnerable to being cracked.

[2 marks]

1 5 The paragraph of text in **Figure 1** is to be compressed using a dictionary-based compression method.

Figure 1

> Unfortunately time after time it is the case that programmers fail to put enough effort into commenting their code. Effort put into commenting could make the code easier to maintain when the time comes to do this.

1 5 . 1 Dictionary-based compression is an example of a lossless encryption method.

Explain the key difference between lossless and lossy compression methods.

[1 mark]

1 5 . 2 Explain how the paragraph of text in **Figure 1** could be compressed using a dictionary-based method.

[2 marks]

1 5 . 3 After the text in **Figure 1** has been compressed it is to be transmitted across a computer network.

Explain why dictionary-based compression is not very effective for compressing small amounts of text for transmission.

[1 mark]

1 6 Discuss the **advantages** and **disadvantages** of representing an image as a vector graphic instead of as a bitmap.

In your answer, include an example for which it would be most appropriate to use a vector graphic and an example for which it would be most appropriate to use a bitmap.

[6 marks]

1 7 . 1 The ciphertext message "BVP" has been received. The message was encrypted using the Vernam cipher and the key "TIN".

Conversion between letters and their equivalent binary patterns was carried out using a special code called the Baudot-Murray code. A version of the Baudot-Murray codes for each letter is shown in **Figure 8**.

Figure 8

Letter	Encoding
A	11000
B	10011
C	01110
D	10010
E	10000
F	10110
G	01011
H	00101
I	01100
J	11010
K	11110
L	01001
M	00111

Letter	Encoding
N	00110
O	00011
P	01101
Q	11101
R	01010
S	10100
T	00001
U	11100
V	01111
W	11001
X	10111
Y	10101
Z	10001

Decrypt the ciphertext to work out what the original plaintext message was.

Express the plaintext as letters.

You **must** show your working.

[3 marks]

Plaintext _____

The Vernam cipher can offer perfect security. Most encrypted transmissions that are made by computers use ciphers that are computationally secure but not perfectly secure.

1 7 . 2 Explain what it means for a cipher to be described as being computationally secure.

[1 mark]

1 8 . 1 A sound has been sampled and recorded. The sound was sampled for 1 minute and 40 seconds at a sample rate of 8000 Hz with a 16-bit sample resolution.

A sample rate of 1 Hz means that one sample has been taken every second.

Calculate the minimum amount of storage space, **in bytes**, needed to store the sampled sound.

You should show your working.

[2 marks]

Answer _____

1 8 . 2 An analogue to digital converter (ADC) was used during the sampling process.

Explain the principles of operation of an ADC.

[2 marks]

Table 2 – Standard AQA assembly language instruction set

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B <condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical XOR (exclusive or) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label the identifier of the label is placed after the branch instruction.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending on whether the first character is a # or an R:

- `#` – use the decimal value specified after the `#`, eg `#25` means use the decimal value 25
- `Rm` – use the value stored in register `m`, eg `R6` means use the value stored in register 6

The available general-purpose registers that the programmer can use are numbered 0–12

1 9 . 1 The Vernam cipher encrypts a plaintext character by performing a logical operation between a character in the plaintext and part of the key.

Write an assembly language program, **using the AQA assembly language instruction set** shown on page 28 in **Table 2**, to encrypt a plaintext character using this method.

You should assume that:

- the character code of the plaintext character to be encrypted is stored in memory location 101
- the part of the key to use to encrypt the character is stored in memory location 102

The encrypted ciphertext character should be stored in memory location 103

[3 marks]

1 9 . 2 A message has been encrypted using the Caesar cipher with a key value of 5

Using the Caesar cipher, each capital letter is replaced by another capital letter (as determined by the key value) whenever it is encrypted or decrypted.

The pseudocode in **Figure 12** is supposed to decrypt a single capital letter character in the message, but it does not work properly.

Figure 12

```
asciicode ← CHAR_TO_INT(ciphertextcharacter)
asciicode ← asciicode - 5
plaintextcharacter ← INT_TO_CHAR(asciicode)
```

- `CHAR_TO_INT` is a function that returns the ASCII code of a character.
- `INT_TO_CHAR` is a function that returns the character corresponding to an ASCII code.

The ASCII code for capital letters is shown in **Figure 13**.

Figure 13

Letter	ASCII Code
A	65
B	66
C	67
D	68
E	69
F	70
G	71
H	72
I	73
J	74
K	75
L	76
M	77

Letter	ASCII Code
N	78
O	79
P	80
Q	81
R	82
S	83
T	84
U	85
V	86
W	87
X	88
Y	89
Z	90

By analysing the pseudocode in **Figure 12**, explain what the problem with the algorithm represented by the pseudocode is **and** how it could be rectified.

[3 marks]

2 0 . 1 A bitmap image is 1000 pixels wide by 800 pixels high.

The image takes up 400 kB of storage space when represented as a bitmap, excluding metadata.

Calculate the maximum number of different colours that could appear in the image.

You should show your working.

[3 marks]

Answer _____

2 0 . 2 The same image can also be represented using vector graphics.

The vector graphics representation of the image takes up 2 kB of storage space.

Explain why the amount of storage space taken up by the vector graphics representation of the image is significantly smaller than the space taken up by the bitmap representation.

[3 marks]

2 0 . 3 One advantage of vector graphics compared to bitmap graphics is that fewer bytes are used to represent an image.

State **two** other advantages of vector graphics compared with bitmap graphics.

[2 marks]

Advantage 1

Advantage 2

2 1 Describe how MIDI is used to represent digital music.

[2 marks]

2 2 . 1 A digital recording was made using a sampling rate of 44 100 Hz with a 16-bit sample resolution.

A sampling rate of 1 Hz means that one sample has been taken every second.

The file, which stores only the recording, is 17.199 megabytes in size.

Calculate the duration of the recording in seconds.

You should show your working.

[3 marks]

Answer _____ seconds

2 2 . 2 MIDI is a system that can be used to enable musical devices to communicate and to represent music on a computer.

Describe the advantages of using MIDI to represent music instead of using sampled sound.

[3 marks]

2 3 . 1 A sound is sampled and recorded digitally. The sound is sampled at a rate of 48 000 samples per second (Hz) for 3 minutes using a 16-bit sample resolution.

Calculate the size of the digital recording, giving your answer in mebibytes.

Give your answer rounded to 2 decimal places.

You should show your working.

[2 marks]

Answer _____ mebibytes

2 3 . 2 The highest frequency component in a different sound is 15 000 Hz.

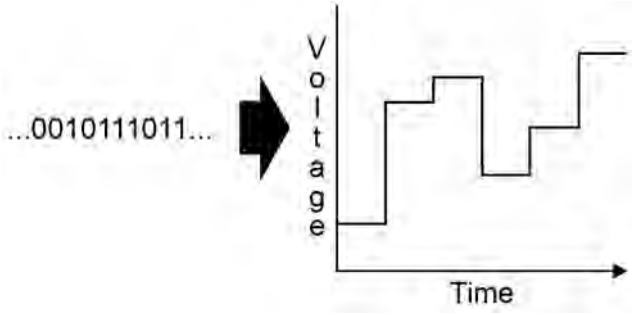
What is the minimum sampling rate that should be used when recording this sound to ensure that all the frequencies in the original waveform are preserved, so that when the recording is played back the original sound is recreated accurately?

[1 mark]

Answer _____ Hz

2 3 . 3 **Figure 1** shows part of the process of playing back a sound that has been sampled. The binary sound data is used to generate an electrical waveform.

Figure 1



A hardware component on a sound card carries out the process shown in **Figure 1**.

State the name of this component.

[1 mark]

2 4 . 1 Encrypt the plaintext SECURITY using the Caesar cipher with a key of 4.

[1 mark]

Plaintext	Ciphertext
SECURITY	

The Caesar cipher is an example of a substitution cipher.

A **different** substitution cipher encrypts letters using the method shown in **Figure 3**.

Figure 3

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

2 4 . 2 State **one** weakness that both the Caesar cipher and the cipher shown in **Figure 3** have which means they can be easily cracked.

[1 mark]

2 4 . 3 State **one** reason why the cipher in **Figure 3** is harder to crack than the Caesar cipher.

[1 mark]

2 4 . 4 The Vernam cipher, unlike the Caesar cipher, can be perfectly secure.

State **two** conditions that must be met for the Vernam cipher to offer perfect security.

[2 marks]

Condition 1: _____

_____

_____

Condition 2: _____

_____

_____

2 5 . 1 A digital camera takes photographs that are 4000 pixels wide by 3000 pixels tall and can contain up to 16 777 216 different colours.

Calculate the size of one image in megabytes.

[2 marks]

Answer _____ megabytes

2 5 . 2 How many images, taken using the camera referred to in Question **02.1**, could be stored on a 256 gigabyte memory card?

You should assume that all of the storage space on the memory card is available to store image data.

Round your answer down to the nearest whole number.

[1 mark]

Answer _____

When a digital camera takes a photograph, an array of photosensors produces analogue voltages representing the amount of light falling on each photosensor. An analogue-to-digital converter then converts these analogue voltages into digital values. These digital values are used to create the pixel data for the bitmap image.

2 5 . 3 Explain why the voltages produced by the photosensors are considered to be analogue **and** why the pixel data is considered to be digital.

[2 marks]

An image is 20 pixels wide by 30 pixels tall. The colour of each pixel is represented using one byte.

Here is a row of data from the original image. The colour of each of the 20 pixels is shown as a decimal value, with commas used to separate the data for the different pixels:

24, 24, 24, 253, 254, 255, 76, 76, 76, 80, 82, 0, 0, 9, 223, 223, 224, 220, 76, 76

The image is to be compressed using Run Length Encoding (RLE). The RLE method used will:

- represent the length of a run using one byte
- represent a colour using one byte.

In decimal, the RLE for the colour of the first four pixels would be:

3, 24, 1, 253

2 5 . 4 Calculate how much memory the row of pixels will take up before **and** after it has been encoded using RLE.

[1 mark]

Memory before RLE (bytes) _____

Memory after RLE (bytes) _____

2 5 . 5 Comment on the effectiveness of the use of RLE to encode the row of pixels in Question **02.4 and** explain why this is the case.

[1 mark]