Exercise walk-through

1.2.1

Encoding a picture and a sound: the file header, the drawing list, and sampling

A-Level Computer Science

You must be able to

- show understanding of how data for a **bitmapped image** are encoded, using the terms **pixel**,
- perform calculations to estimate the file size for a bitmap image
- show understanding of the effects of changing elements of a bitmap image on image quality and
- show understanding of how data for a **vector graphic** are encoded, using the terms **drawing
- justify the use of a bitmap image or a vector graphic for a given task
- show understanding of how sound is represented and encoded, using the terms **sampling**,
- show understanding of the impact of changing the sampling rate and resolution, including the

1 The method

Method — A bitmap is a header followed by pixels

A **bitmapped image** is stored as a grid of **pixels** – “picture elements”, the smallest addressable dot – each holding one binary colour value. But the pixels alone are meaningless: a file of 786 432 numbers could be 1024 rows of 768 or 768 rows of 1024. So every bitmap file begins with a **file header**.

the file header holds	**the pixel data holds**
the file format, the width and height in pixels, the **colour depth**, and often a colour palette	one binary value per pixel, row by row

Method — A bitmap is a header followed by pixels

The five terms, and the differences students lose marks on:

- **Pixel** – one dot of the image, the smallest element that can be given its own colour.
- **Colour depth** (**bit depth**) – the number of **bits used to store one pixel**. *n* bits give 2^n different colours: 1 bit gives 2, 8 bits give 256, 24 bits give over 16 million.
- **Image resolution** – the number of pixels **in the image**, e.g. 1920×1080.
- **Screen resolution** – the number of pixels **the display has**. △ These two are different things, and the mark scheme separates them: an image of higher resolution than the screen cannot be shown at full detail, and the same image looks smaller on a higher-resolution screen.
- **File size** $=$ image resolution $\times$ colour depth $(+$ the header$)$, and the header is small enough that "estimate" means you may leave it out – but say that you have.

Method — A bitmap is a header followed by pixels

What changes what. Increasing the **image resolution** stores more pixels, so more detail and a proportionally larger file. Increasing the **colour depth** stores more bits per pixel, so smoother colour gradients and a proportionally larger file. Reducing either loses information **permanently** – the discarded detail cannot be recovered by enlarging the image again.

Method — A vector is a list of instructions

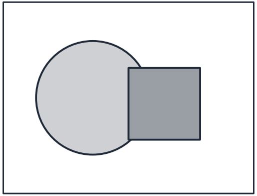
- A **drawing object** is one shape in the picture: a circle, a rectangle, a line, a piece of text.
- Its **properties** are the values needed to draw it – position, size, fill colour, line colour and thickness. A circle's properties are its centre and radius; a rectangle's are a corner, a width and a height.
- The **drawing list** is the whole file: every drawing object with its properties, **in the order they are drawn** – which is what decides which shape appears on top.

Justifying one over the other. A **vector** when the picture is made of shapes and must scale: logos, diagrams, maps, fonts. Its file size depends on the **number of objects**, not on the size it is displayed at, and enlarging it re-runs the instructions so edges stay sharp. A **bitmap** when the picture is made of continuously varying colour: photographs, scans. No realistic drawing list could describe a photograph – and enlarging a bitmap only makes each stored pixel bigger, which is what "blocky" or "pixelated" means.

Method — A vector is a list of instructions

Justifying one over the other.

what you see



Drawing list	*the whole file: the objects, in the order they are drawn*
1 Circle	centre (150, 160) radius 95 fill light line black, 1pt
2 Rectangle	corner (210, 90) width 120 height 120 fill mid
*a **drawing object***	*its **properties** – everything needed to redraw it at any size*

A vector graphic stores *instructions*, not pixels. Enlarging it re-runs those instructions at the new size, so the edges stay sharp and the file size does not change – which is why a logo is a vector and a photograph is not: no drawing list could describe every leaf on a tree.

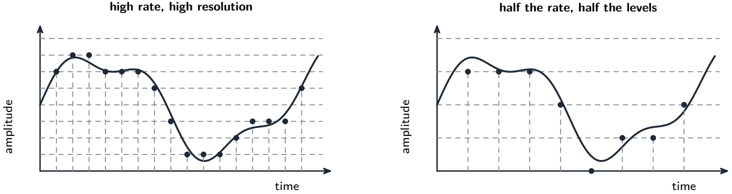
Method — Sound is made digital by sampling

- **Analogue data** varies **continuously** and can take any value; **digital data** is stored as a fixed set of discrete binary values. A sound wave arriving at a microphone is analogue; the file is digital.
- **Sampling** is measuring the **amplitude** of the wave at regular intervals and recording each measurement as a binary number.
- **Sampling rate** – how many samples are taken **per second**, measured in **hertz**.
- **Sampling resolution** – the number of **bits used for each sample**, which fixes how many different amplitude levels a measurement can be rounded to.
- Raising **either** makes the stored version follow the original wave more closely, so the playback is more accurate – and makes the file **proportionally larger**. Halving either halves the file and loses accuracy.

△ Do not write "sampling rate is how accurate it is". Rate and resolution improve accuracy in **different ways**: rate captures more of the changes **over time**, resolution captures each measurement **more precisely**.

Method — Sound is made digital by sampling

△ Do not write “sampling rate is how accurate it is”.



sampling rate is how often a measurement is taken – the *horizontal* spacing, in hertz

sampling resolution is how many bits each measurement gets – the number of *vertical* levels it may be snapped to

Sound is **analogue**: it varies smoothly and without limit. Sampling makes it **digital** by measuring the amplitude at fixed instants and rounding each measurement to the nearest level a whole number of bits can hold. Raising *either* the rate or the resolution follows the wave more closely – and makes the file larger in exact proportion.

An analogue wave sampled at two different rates and resolutions

2 Practice

Practice 2.1 ▪ 3 marks

State **three** items of data stored in the **file header** of a bitmapped image.

Solution 2.1

Method: A bitmap is a header followed by pixels — p.4

Worked steps

any **three** of: **B1** *each*

- the file format or file type; the width of the image in pixels; the height in pixels; the **colour depth** (bits per pixel); the colour palette

Practice 2.2 ▪ 2 marks

Explain the difference between **image resolution** and **screen resolution**.

Solution 2.2

Method: A bitmap is a header followed by pixels — p.4

Worked steps

- **image resolution** is the number of pixels in the **image** itself, for example 1920×1080 B1
- **screen resolution** is the number of pixels the **display** has, so the same image looks smaller on a higher-resolution screen, and an image with more pixels than the screen cannot be shown at full detail B1

Practice 2.3 ▪ 3 marks

A vector graphic contains one circle. State what is meant by a **drawing object** and by a **property**, using this circle as your example.

Solution 2.3

Method: A vector is a list of instructions — p.7

Worked steps

- a **drawing object** is one shape in the picture – here, the circle itself B1
- a **property** is a value stored for that object which is needed to draw it B1
- for a circle the properties are its **centre** and **radius**, together with its fill colour and its line colour and thickness B1

Practice 2.4 ▪ 2 marks

Explain the difference between **analogue** and **digital** data, using sound as your example.

Solution 2.4

Method: Sound is made digital by sampling — p.9

Worked steps

- **analogue** data varies **continuously** and may take any value – the pressure wave arriving at the microphone **B1**
- **digital** data is stored as a fixed set of discrete binary values – the numbers written into the sound file **B1**

Practice 2.5 ▪ 2 marks

State what is meant by the **sampling resolution** of a sound recording.

Solution 2.5

Method: Sound is made digital by sampling — p.9

Worked steps

- the number of **bits used to store each sample** **B1**
- which fixes how many different amplitude levels a measurement may be rounded to: n bits give 2^n levels **B1**

3 Exam-style

Exam-style 3.1 ▪ 1 mark

Which term describes the number of bits used to store each measurement of a sound wave?

A sampling rate

B sampling resolution

C colour depth

D image resolution

Solution 3.1

Method: Sound is made digital by sampling — p.9

- **A** sampling rate
- **B** sampling resolution ✓
- **C** colour depth
- **D** image resolution

Worked steps

B

- the number of bits per sample is the **sampling resolution** B1
- the sampling **rate** (**A**) is samples per second; **C** and **D** are image terms

Exam-style 3.2 ▪ 7 marks

A designer creates a company logo as a **vector graphic**. It consists of a circle with a square drawn on top of it.

Exam-style 3.2 (a) ▪ 2 marks

State what is meant by a **drawing list**.

Solution 3.2 (a)

Method: A vector is a list of instructions — p.7

Worked steps

- the drawing list is the file: every **drawing object** in the picture, each with its **properties** B1
- stored in the order in which they are drawn, which decides which shape appears on top B1

Exam-style 3.2 (b) ▪ 3 marks

State the two drawing objects in this logo, and give **two** properties that would be stored for the circle.

Solution 3.2 (b)

Worked steps

- the drawing objects are a **circle** and a **square** (or rectangle) **B1**
- two properties of the circle, from: its **centre** coordinates; its **radius**; its fill colour; its line colour; its line thickness **B1** *for two*
- (a property must be a stored *value*, not "it is round")

Exam-style 3.2 (c) ▪ 2 marks

The logo is enlarged to fill a billboard. Explain why it stays sharp, whereas a bitmap of the same logo would not.

Solution 3.2 (c)

Worked steps

- a vector stores **instructions**, so enlarging it redraws the circle and the square at the new size and the edges are recalculated – they stay sharp **B1**
- a bitmap stores a fixed grid of pixels, so enlarging it only makes each stored pixel bigger; no extra detail exists to show, and the image looks blocky **B1**

Exam-style 3.3 ▪ 10 marks

A phone app records voice memos.

Exam-style 3.3 (a) ▪ 3 marks

Explain how the analogue sound arriving at the microphone is turned into digital data.

Solution 3.3 (a)

Method: Sound is made digital by sampling — p.9

Worked steps

- the amplitude of the wave is measured at **regular intervals** – this is **sampling** B1
- each measurement is **rounded** to the nearest level that the available number of bits can represent B1
- and stored as a **binary number**; the device that does this is an analogue-to-digital converter B1

Exam-style 3.3 (b) ▪ 2 marks

State what is meant by the **sampling rate**, and give the unit in which it is measured.

Solution 3.3 (b)

Worked steps

- the sampling rate is the number of samples taken **per second** B1
- measured in **hertz** (Hz) B1

Exam-style 3.3 (c) ▪ 3 marks

The app offers a *voice* setting ($8\,000$ Hz, 8-bit) and a *music* setting ($44\,100$ Hz, 16-bit). Explain the effect on the **accuracy** of the recording and on the **file size** of choosing *music* instead of *voice*.

Solution 3.3 (c)

Worked steps

- **accuracy**: 44 100 samples a second captures far more of the wave's changes over time than 8 000, and 16 bits allows $65\,536$ amplitude levels instead of 256, so each measurement is closer to the true value – the playback is noticeably more faithful **B1**
- both effects together make the recording follow the original wave much more closely **B1**
- **file size**: the rate rises by a factor of about 5.5 and the resolution by a factor of 2, so the file is about **11 times larger** for the same length of recording **B1**

Exam-style 3.3 (d) ▪ 2 marks

The developers consider raising the *music* sampling rate far above $44\,100$ Hz. Explain why this would increase the file size without a listener noticing any improvement.

Solution 3.3 (d)

Worked steps

- a higher sampling rate stores proportionally more samples per second, so the file grows in exact proportion **B1**
- but human hearing has an upper frequency limit, and once the rate is high enough to capture every frequency a listener can hear, the extra samples record nothing that can be heard **B1**