PONTEFRACT
ACADEMIES TRUST

OUT OF LESSON WORK

TERM 1

COMPUTER SCIENCE

YEAR 11

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Year 11

Computer Science

Workbook

Component 1

Name _____

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Knowledge, Understanding and Skills	Process Goal	Performance Goal
Component 1 – Theory		
Systems Architecture	Refer to the fetch-execute cycle when talking about components and performance Link the components together when describing how the processor works	Be able to explain clearly the function of all the components of the processor Be able to explain the fetch-execute cycle Be able to explain how to improve processor performance
Memory and Storage	Use the standard list of features when comparing memory and storage technologies	Be able to recommend a storage device for a given situation
Network Technologies	Use the TCP/IP model when describing network technologies	Be able to explain how data is transmitted across a network
System Security	Use the standard list of security threats and solutions Link each threat to the correct solution(s) and combine security solution Start with people as the weak point in a system	Achieve top band in each essay answer Achieve full marks on explain questions
Ethical, Legal, Cultural and Environmental Concerns	Refer to all the points given in the question Write using a top-band structure Discuss issues from more than one point of	Achieve top band in each essay answer

Systems Architecture

Topic Revision

Systems Architecture

Question

Explain two ways to improve the performance of a computer system [6]

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Describe how the CPU processes instructions [6]

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Example answers

Explain two ways to improve the performance of a computer system [6]

- One way to improve the performance of a computer system is to increase the size of the cache memory on the processor.
- The cache is used to store commonly used instructions, which reduces the number of fetch operations to fetch instructions from the RAM.
- Fetching data from the RAM is slow, so reduces the number of fetch operations speeds up the execution of a program.

- Another way to improve computer system performance is to add a graphics card.
- The graphics card contains specialised processors that are optimised to process graphics, for example by parallel processing.
- This improves the run time of graphics programs as the graphics routines are executed more quickly.
- Furthermore, graphics processing is handled by the graphics card, so the main CPU can process other instructions, allowing the system to process more data in the same timeframe as a system without a dedicated graphics processor.

There are several ways given in the specification to improve system performance. I have picked two – you may have picked others. The full list is given in the revision notes.

You get 3 marks *per method* of improving performance:
1 mark for stating how to improve it, e.g. increase cache size
2 marks for explaining how the change improves performance

Notice how the full mark answer develops each point.

- The points are linked in a logical order.
- The answer shows coverage of the key points in the specification.
- You can add detail by
    - Explaining what the component does or how it works
    - Referring to the fetch-execute cycle (using technical language and linking topics)
    - Explaining where the increase in performance comes from

Describe how the CPU processes instructions [6]

- The CPU fetches the next instruction to be processed from the RAM.
- The address of the next instruction is stored in the program counter.
- The address is passed to the memory address register

    - and the data is fetched from the RAM into the memory data register.
- The instruction is decoded by the processor
    - which executes the instruction.
- The control unit controls the fetch execute cycle
    - by sending control signals to all the components connected to the processor.

(Up to 6 marks for valid steps)

You need to know this list of steps for the F-E cycle.
Make sure that you refer to the components of the CPU and link them to the F-E cycle

Practice questions

Use the same mark scheme as the Question questions and check your points against the notes.

Describe how the CPU processes data, referring to the following in your answer: [6]
* The fetch-execute cycle
* RAM
* registers in the CPU

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Explain how each of the following will improve computer system performance [3 marks each]

- Increasing the number of cores
- Increasing the cache size
- Increasing the clock speed
- Increasing the amount of RAM
- Adding a graphics card

Note that this is too big for a normal exam question. However, you might as well practice all of them for revision. In a real exam question you might only be asked about two or three specific ways, or you may be able to choose your own examples.

Number of cores [3]

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Cache size [3]

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Clock speed [3]

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RAM [3]

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Graphics card [3]

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Memory and Storage

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Memory and Storage

The table below shows the standard ways to compare storage technologies. You will need to apply these criteria to different scenarios.

Technology	Example devices	Capacity	Read/ Write Speed	Portability	Durability	Reliability	Cost	Common uses
Optical	CD, DVD, Blu-ray(TM)	Low	Slow	Reasonable. Small and light.	Immune to magnetic fields, but easily scratched.	Reasonable. Data cannot be overwritten. However, fewer devices now have DVD players.	Low	Sending SW, backing up files e.g. photos
Magnetic	Hard Disk (Built in and portable)	High	Medium – faster than optical, but slower than solid state	Poor. Many moving parts, so needs to be still when in use. Much larger than other media.	Not great, Susceptible to damage from movement and from magnetic fields.	Very good. Hard disk can be overwritten many times.	Low per GB, but quite expensive	Secondary storage in PC or network. Portable HDD are also popular for backing up files
Solid State	Solid State Hard Disk, SD card, Flash drive/memory stick	Medium	Fast	Very portable. Can be made into tiny memory cards. No moving parts, so can be used on the move	Very durable.	Very good. Most devices have USB connections for memory sticks. However, SD cards require special readers. Also, solid state	High per GB	Moving devices, e.g. cameras, phones, drones. High-performance PCs, Laptops

						drives can be written to fewer times than magnetic media.		

Question

Alice is going on holiday at the end of year 11 and is taking her digital camera and laptop to record her journey. She wants to be able to store photos and videos of her trip. She will transfer the files to her laptop each day so that she has enough space on her camera for more images. She also wants to keep a backup copy of her photos and videos in case her laptop is damaged or stolen.

The camera uses solid state memory.
Explain two reasons why this is the most appropriate storage technology for this device. [6]

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Alice is considering two ways to back up her files
* On a memory stick
* On a portable hard drive

Discuss which solution would be the most appropriate. * Your quality of written communication will be assessed in this answer [8]

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Question mark scheme and notes

The camera uses solid state memory.
Explain why this is the most appropriate storage technology for this device.

- Solid state memory has no moving parts
    - and therefore, it is not affected by movement.
        - This is important in a camera because the camera may be in motion when data is being written to the SD card
            - especially if she is filming a tracking shot

- Solid state memory has very fast write times
    - which means that the camera can store more data per second
        - This means that the camera can store more frames per second
            - so it can record in slow motion
            - or it can take pictures faster

You could have used any two of the features from the table – why not try the question again and use two different criteria

To get 3 marks for a reason you need
1 mark for identifying a correct feature of the technology *from the standard list in the table*
1 mark for describing the benefit of this feature
1 mark for linking this back to the context

Don't just go for the first one you think of, e.g. small; you need to pick something you can write about in detail.

Notice again how the extra marks are gained by adding clear technical details taken from the table.
Also notice how the notes in the table are linked back to the context, for example linking the read/write time to the frame rate of the camera.

If you are not sure about the context/detail, consider using "maybe" in the sentence or giving a range of examples such as in the second answer.

Alice is considering two ways to back up her files
* On a memory stick
* On a portable hard drive

Discuss which solution would be the most appropriate.

Example answer:
A memory stick may be appropriate because it is **very small** and **is therefore portable**. Also, memory sticks are now **relatively cheap for their capacity**. However, depending on how long she is travelling, a memory stick **might not have enough capacity for her videos**, which **may be very large files**. Furthermore, **a small memory stick might also be easy to lose** while she is travelling.

An alternative option would be a portable hard drive. This may be **larger than a memory stick,** however modern portable drives are **not much bigger**. Furthermore, portable hard drives can have a **very large capacity, potentially up to a terabyte**, so she should be **able to store all her videos** and photos. Portable hard drives **are sensitive to movement** when they are being accessed, but Alice can back up her files when appropriate, so this should not be a factor. Also, **rugged cases for hard drives are cheap** and this would help her to protect her data.

Overall, **I think that the best choice would be** a portable hard drive **because** the increased capacity and reduced risk of losing the drive make it more useful for backing up large files while travelling.

This should get a top band because:
- Both points given in the question are discussed
- It considers a range of technological features from the table
- It uses clear paragraphs and connectives to have a top-band style
- Each point is discussed with pros and cons related to the context give
- There is a clear conclusion based on the arguments already made

Practice

Software companies often sell software on DVD.
Explain why this is a suitable medium to distribute software [4]

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Alice is going on holiday at the end of year 11 and is taking her digital camera and laptop to record her journey. She wants to be able to store photos and videos of her trip. She will transfer the files to her laptop each day so that she has enough space on her camera for more images. She also wants to keep a backup copy of her photos and videos in case her laptop is damaged or stolen.

Alice is considering backing up her photos to the cloud.
Discuss whether this is a suitable choice* Your quality of written communication will be assessed in this answer. [8]

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A manufacturer is making a high-quality slow motion digital video camera for students to record science experiments. Discuss which form of storage would be most appropriate for this device* [8]

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Software companies often sell software on DVD.
Explain why this is a suitable medium to distribute software [4]

Points may include:

- Small, light and flat,
  - so easy to package and easy to post
- Very cheap for capacity,
  - so easy to mass produce
- Capacity is appropriate for modern installers
  - which are relatively small
  - because extra content can be downloaded via the internet once the SW is installed

1 mark for a valid point
1 mark for explanation of point related to the context

Alice is considering backing up her photos to the cloud. Discuss whether this is a good choice. [8]

Points for

- Many devices have automatic uploads
  - so she doesn't need to remember to back up the files
  - so she is less likely to lose them

- Cloud storage is free on some services/she may already have cloud storage through school or work
  - so there is no additional cost for the backup

- Cloud storage capacity is very large
  - possibly unlimited
  - and she can buy extra space easily if she needs it

Points against

- Backing up to cloud storage requires an internet connection
  - which she may not have if she is abroad
  - or may cost more
    - particularly if she needs to use a mobile connection
    - or pay for internet access in a hotel/internet cafe

- Automatic backups could be expensive
  - if she inadvertently incurs data roaming charges

Conclusion

If she is expecting to have reliable internet connection then cloud storage is a good idea. However, if she is somewhere without internet then she will need another solution, such as a portable hard drive.

Full marks if

- You several points for and against (at least two of each)
- You made clear technical points from the table
- Your points were linked back to the context of travelling
- You made a valid conclusion based on your points

A manufacturer is making a high-quality slow motion digital video camera for students to record science experiments. Discuss which form of storage would be most appropriate for this device. [8]

Possible points

SD Card

Points for

* Fast read-write times
  which are good for slow-motion

* Very small
  keeping camera small/light
  and therefore easier to students to use

* Very robust
  useful if the camera may be used by students

* can be removed/replaced
  so students can keep their own videos/other groups of students can use the camera

* Good capacity
  May be sufficient for videos – often used in cameras

Points against

* is the read/write time fast enough, or is a solid-state drive needed?
* is there a risk of the cards being lost?
* is the capacity large enough for the quality of video?

Solid state hard drive

Points for

* Very large capacity
  for storing large amounts of high-quality slow motion video

* Very fast read-write times
  for storing high frame rate

Points against

* Very expensive
  Is the device too expensive?

*very bulky/heavy
  not ideal in a portable camera

Students may also discuss DVD as a possible storage method

Full marks if

- You considered two or more solutions
- You made clear technical points about each one
- and linked these to the context pf a camera for students

- and you drew a valid conclusion based on your arguments

Networks

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Networks

Question

I have written an email on my mail client on my phone. When I press send, the email is sent to my mail server using the address mail.school.co.uk
Explain how the email is sent to my mail server. [6]

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Question mark scheme and notes

1 mark per valid point to max 6
For 6 marks, the answer must reference

- The sending device
- Routers
- The receiving device

- First the sending device will look up the IP address of the mail server on a DNS server.
    - This is a database that matches IP address with domain names.
- Next the data is split into packets.
    - Each packet is given the source and destination IP address
    - and also a sequence number.
- The packets are sent onto the internet.
    - Routers use the destination IP addresses to send the data to the mail server by the most efficient route.
    - Each packet may take a different route.
- The mail server receives the packets and uses the sequence numbers to reassemble them into the right order.
    - If any packets are missing the mail server can send a request that the packet is resent.

Notice that this is just an explain question, not an essay, so there are no marks for the quality of written communication.

- This means that you can list the key points in clear sentences.
- Make sure that you cover all the key devices – they weren't given in the question, but it still helps to talk about senders, receivers and routers.
- Remember to talk about devices not people!

Networks is a big topic
There is a lot to remember – it may help to turn the notes into a large, labelled diagram.
It helps if you can remember the basic principles in the TCP/IP model – this will help you to fill in any gaps.

Remember that networks are designed using the same principles as the phone system or the post office. If you think about making a phone call, or sending a letter, then you already know the main steps and principles!

Practice

Explain how the following devices are used when a computer connects to a website

Router [2]

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DNS Server [2]

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Ethernet card [2]

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Explain the importance of protocols in network communications, giving an example of a common protocol [4]

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Practice answers

Explain how the following devices are used when a computer connects to a website

Router

- Uses the destination IP address
- in a packet
- to route the packet to the destination by the quickest route
- Routers can route packets around network congestion

DNS Server

- A DNS server converts a Domain Name
    - such as google.com
- into an IP address

Ethernet card

- An Ethernet card allows a computer to connect to a network
- by converting data into the correct format to be sent on the network
- such as via an Ethernet cable

Explain the importance of protocols in network communications, giving an example of a common protocol

- Protocols are a standard for communication
    - which means that any device or software using the protocols can connect to any other device or service using the same protocols
        - **For example**, a webserver will be set up to send and receive traffic using the **http protocol**
            - which can be read and displayed by any web browser

You must have an example of a protocol for full marks.

Security

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Security

There are two ways to think about security

- know the risks and think about solutions
- know security strategies and think about the problems they solve

While there is a solution to each risk, in many cases you will need to consider either multiple solutions to one risk or multiple benefits of one strategy. The problems and solutions overlap in many ways. Use this to help you remember the points or develop an answer – if you can remember one point, the links may help you to remember more.

When analysing a scenario, you may want to consider the following principles:

- Most data loss is accidental, either by employee error or employees losing laptops, memory sticks etc.
- Most malicious damage is done by employees not hackers
    - either for money
    - or for revenge

The people are the biggest risk

- Training staff
- Control access to systems
- Have software in place to monitor systems
- Reduce external data, e.g. Internet access, USB memory sticks etc.
- Don't allow staff to use their own devices, or take sensitive data off site

Any automated systems, security check etc. need to be

- Up to date, to deal with the latest threats
- Repeated at regular intervals

Some specific risks and strategies are summarised in the notes. Check your specification carefully, as the required examples are slightly different for each exam board.

Question

A school has developed a revision app for students. Students can sign up and then log in to complete tasks and receive feedback. The app stores data about the students, such as target grades and SEN needs to help tailor the questions to their needs.

Explain two security risks to the system and how they may be reduced. [6]

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Question mark scheme

A school has developed a revision app for students. Students can sign up and then log in to complete tasks and receive feedback. The app stores data about the students, such as target grades and SEN needs to help tailor the questions to their needs.

Explain two security risks to the system and how they may be reduced. [6]

Example answer

- One risk is theft of sensitive data about the students.
    - This could be through hackers accessing the data stored by the app.
- One way hackers could do this is by a brute force attack to find a user's password.
    - To reduce this risk the system should indicate to students how strong their password is and only allow passwords that meet secure conditions,
        - such as being longer that 8 characters.
    - Furthermore, the system should lock after three wrong password attempts
        - to stop hackers using software to automatically try large numbers of passwords.
- The system could also use Captcha's or similar tools to prevent automated attacks by bots.
- To further reduce the risks from theft, the data stored by the system should be encrypted so that stolen data cannot be read by thieves.

- Another risk is SQL injection.
- A hacker could access the app data by typing SQL commands into input forms on the site.
    - This risk can be reduced by ensuring that all inputs in forms are validated,
    - and any command characters are removed before the input is processed.
    - Many web authoring packages include SQL injection protection as standard.

The answer here is more than is needed for 6 marks, to show you how each answer can be extended.

For three marks, you need

- A valid risk from the table
- A description of what the risk is
- One suggestion of how to reduce the risk

You need to explain two risks and you get three marks per risk explained

You can redo this question several times, picking a different two risks each time.
You can also flip the question and ask, "Explain two ways the data in the app can be protected from theft."

There are many variations on this question.
Make sure you can get three marks for each risk and solution listed in your specification.

Practice

A school stores a large amount of student data on its network, including medical details for trips.

Explain three risks to the school network, and steps the school can take to reduce these risks. [9]

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Ethical, Legal, Social, Cultural and Environmental issues

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Ethical, Legal, Social, Cultural and Environmental issues

This is a very broad topic and is likely to be an essay.

Good practice is to read regularly the technology sections of national newspapers or websites to consider the big topics in computing.

You will need to be able to discuss the scenario given from several points of view – there may be prompts for this given in the question.

It may be easiest to approach the scenario with a series of questions that you can then discuss. Some possible starting points for discussion are given below.

Use the writing structures given at the start of the booklet particularly
point-counter point-reinforce original point

Issue	Prompt Questions
Ethical issues	What is morally right? What is socially right? Who benefits? Who loses out? Do users understand what they are doing? Do users have choices? Can they opt in and/or opt out? Does the digital divide get bigger?
Legal issues	Is there any data to protect?
Cultural issues	Does everyone have access? Is there any discrimination?
Environmental issues	How is the tech made? How is old tech disposed of?
Privacy issues	Is user data kept secure? Is the data protection act followed?
Stakeholders	Who will use this? Who needs it? How are businesses affected? How are consumers affected?
Technology	What new technology is needed?

Question

A tech business is considering developing a new fitness watch. Discuss the issues they will need to consider when developing their device including:

- Stakeholders
- Technology
- Ethical issues
- Environmental issues
- Legal issues

Your quality of written communication will be assessed in this answer.

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Example essay

The tech business will need to consider the needs of the owners or shareholders in the business, who will be keen that the device is profitable for the company. This means that the device must be manufactured cheaply enough to turn a profit, while maintaining quality to keep the consumers happy. There is an ethical issue here as the company should not use exploitative manufacturing methods and should consider using renewable resources.

Consumers will be keen that the watch is compatible with a range of smart phones and devices, so that they can use the watch with their existing devices. The company can achieve this by using existing standards for connectivity, such as Bluetooth and USB. This will also help to ensure that their device sells into a larger market. The company must also ensure that the device doesn't adversely affect any existing devices with which it is used.

The company should consider making the watch robust enough to last for several years, both in terms of the reliability of its hardware and in terms of its software. The device should be able to be updated as other technology and apps develop. To achieve this the developer could use a standard operating system with the ability to receive automatic updates. The developer could consider using an open-source OS to allow other developers and users to develop or maintain the device in the future. It is more environmentally friendly if devices last longer as there is less waste, however consumers may still want a new device anyway.

The fitness watch may collect data about the user, such as their location, and the company needs to ensure the security of the user's data. For example, the device could include a password to unlock it. Any data sent to the company should be encrypted before it is transmitted, so that it cannot be read if it is intercepted. Furthermore, if any data is stored by the company, they must store it securely, in line with the data protection act. The company must be clear with the user what data will be collected and how it shall be used.

The watch may also include sensors such as a microphone for voice control. While this is a useful feature for the user, there is a security risk if the device is hacked; the microphone could be used to monitor users without their knowledge. Therefore, the company must make sure that the watch includes appropriate security measures, for example, meeting industry standards and using well established security protocols. The company should carry out sufficient testing to ensure that the device and any security measures are robust, including penetration testing on their own network.

Notice the following for a top band

- All the prompts in the question have been addressed
- The answers draw in technical content from across the specification
- Each point is quite brief, but the points are well linked so they give a wide range of issues related to the context.
- Everything is related back to the context, including a min-conclusion for each paragraph giving the impact on the company or the actions they must take to address the issue

Practice

Discuss the issues relating to the introduction of driverless cars, including:

- Legal issues
- Ethical issues
- Environmental issues

Your quality of written communication will be assessed in this answer

Practice essay
Suggested points

Legal issues

- Who is culpable in a crash? The driver? The manufacturer?
- Who has responsibility for testing the car? The programmer? The manufacturer? The retailer?
- What data is collect by the vehicle? How is it stored in line with the data protection act? Does it meet the RIPA? (I.e. can the manufacturer spy on your movements?)
- Who sets the standards for controlling communication between cars?

Note that data could improve legal cases if it can be used to prove responsibility in a crash

Ethical issues

- Can AI make decisions in life-threatening situations?
- Who is responsible for safety?
- What data is gathered? Is it used ethically and with full knowledge of the drivers?

- Driverless cars can improve mobility, particularly for the elderly/sick
- Driverless cars may be safer, if set up correctly
- May be some early risks that pay off later, like air travel – are we willing to take that risk?

Environmental issues

- may improve air quality if AI drives more economically
- may reduce fuel use
- may result in scrappage of old cars – could be both good or bad
- If cars can run more closely, would traffic increase?

Note that these are not marking points per se. Rather they are prompts for points that you may have considered. To get the top band you don't need to make these specific points, rather you need to:

- Make a range of technical points
- Consider all the prompts in the question
- Consider different points of view
- Back up your points with evidence and examples

Some of the points are open-ended and there is no single right/wrong answer.

If you are not sure if you would get the top band, then your work is probably not clear enough yet.

More essay practice

Discuss the ethical and legal issues for an ISP monitoring customer Internet use

Discuss the impact of increasing use of mobile technology on young people

Discuss the benefits and risks of a large business allowing staff to use their mobile devices on the company Wi-Fi

"All major operating systems should be open source".
Discuss how far you agree with this statement.

A tech firm is considering developing smart implants for people who have lost limbs in accidents.
Discuss the ethical, legal and environmental issues they need to consider.

Component 2 – Algorithms and Programming

Writing code

Question

Write a function to convert a 2-digit hexadecimal number into denary. The hexadecimal number is passed as a parameter to the function. The subroutine hex_digit(x) converts a single hex digit from 0 to F into the equivalent denary number and you may use this function in your solution if you wish. [5]

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Here are the names and test marks for several students on different topics, stored in a 2D array called scores.
scores[0,0] is "Alex", scores[0,1] is 80 and scores[1,0] is "Bob"
Write an algorithm to find the range of the marks [8]

Alex	80	85	83	79	92
Bob	87	88	90	84	87
Charlie	95	95	100	95	95
Danni	92	93	92	96	98

Explain the benefits of defensive programming [4]

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Explain two features of an IDE that help developers write robust code [6]

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Question mark scheme

Writing code for an unseen problem is one of the hardest skills in computer science.
Luckily, the whole subject is designed to give you a method to use to solve an unseen problem!
Hopefully you already have plenty of experience writing your own code and solving problems.

Before we analyse the diagnostic questions, here are some standard algorithms and coding patterns you should be able to recognise, write and use.

Standard algorithms and techniques

Switch-case statement

Used for: Choosing one of a list of possible options
Example

```
function calculate(x, y, operator)
  switch operator:
      case +:
          return  x + y
      case -:
          return x – y
      case *:
          return x*y
      case /:
          return x/y
      case default:
          return "unknown operator"
```

If-else statement

Used for: deciding if something has happened

```
if mark > 40 then
   return pass
```

```
if mark > 40 then
   return pass
else
   return fail
```

Nested if are similar to a switch-case statement

```
if mark > 80 then
   return top band
else
   if mark > 40 then
      return pass
   else
      return fail
```

For loop

Used for: looping through a list of items OR looping a fixed number of times

Example

Make sure you can loop through the items in a list or 1D array, using the indexes

```
prices = [10, 12, 30, 5, 7]
for i = 0 to 4
   print(prices[i])
next i
```

You can use two for loops to go through a 2D array

```
board =        [[0, 0, 0],
               [1, 0, 0],
               [0, 0, 0]]

for i = 0 to 2
   for j = 0 to 2
      print(board[i,j])
   next j
next i
```

You can combine a loop with a flag variable and an if statement to check if something occurs in the list

```
flag = False
prices = [10, 12, 30, 5, 7]
for i = 0 to 4
   if prices[i] > 10 then
      flag  = True
   end if
next i
if flag then
   print("There are items over £10")
end if
```

Conditional loop

Used for: looping an unknown number of times

Examples

```
password = ""
while len(password) < 8 do
   INPUT password
end while
```

Some standard list patterns

Finding a total

Using the "in" pattern

```
total = 0
for value in list
   total = total + value
print total
```

Using a while loop and an index

```
total = 0
i = 0
while i < len(list)
   total = total + list[i]
   i = i + 1
print total
```

Using a for loop and the index (we will use this pattern)

```
total = 0
for i = 0 to len(list) – 1
   total = total + list[i]
next i
print total
```

Finding minimum value

```
min = list[0]
for i = 1 to len(list) – 1
   if list[i] < min then
      min = list[i]
   end if
next i
print min
```

Counting something in a list

```
count = 0
for i = 0 to len(list) – 1
   if list[i] == value_to_find then
      count = count + 1
   end if
next i
print count
```

Combining ideas – finding the average of all the items over £100

```
total = 0
count = 0
for i = 0 to len(list) – 1
   if list[i] > 100 then
      total = total + list[i]
      count = count + 1
   end if
next i
average = total / count
print average
```

Find the student with the highest average grade across the five tests and print their name and average score.
Scores is a 2D array as before

	Test1	Test2	Test3	Test4	Test5
Alex	80	85	83	79	92
Bob	87	88	90	84	87
Charlie	95	95	100	95	95
Danni	92	93	92	96	98

```
max_value = 0
max_name = ""
for i = 0 to 4
   total = 0
   for j = 1 to 5
      total = total + scores[i,j]
   next j
   average = total/5
   if average > max_value then
      max_value = average
      max_name = scores[i,0]
   end if
next i
print max_name, max_value
```

Here's how to build up the last answer in stages:

1) Loop through all the scores for all the students

```
for i = 0 to 4
   for j = 1 to 5

   next j
next i
```

2)
Calculate the average for one student

```
for i = 0 to 4
   total = 0
   for j = 1 to 5
      total = total + scores[i,j]
   next j
   average = total/5
next i
```

3)
Check if the average is a maximum

```
max_value = 0
max_name = ""
for i = 0 to 4
   total = 0
   for j = 1 to 5
      total = total + scores[i,j]
   next j
   average = total/5
   if average > max_value then
      max_value = average
      max_name = scores[i,0]
   end if
next i
```

4)

```
Print the results
max_value = 0
max_name = ""
for i = 0 to 4
   total = 0
   for j = 1 to 5
      total = total + scores[i,j]
   next j
   average = total/5
   if average > max_value then
      max_value = average
      max_name = scores[i,0]
   end if
next i
print max_name, max_value
```

Armed with these standard patterms, you can now use some or all of the following problem solving strategy...

Problem solving strategy

1) List the main steps of the problem
2) Break these down into sub steps
    You may need to re-order or add steps
3) Spot any standard patterns, e.g. is this a 2D array, i.e. two for loops?
4) Identify any decisions – these are your if statements
5) Identify any calculations
6) Identify any loops – does anything need repeating?
7) Idenifty any variables
    these will be the nouns in your bullet points
    Do you need any variables for your calculations? Any temporary results? Any counters etc. for your loops?
8) Start writing your code
    Define you function
        What is its name? What are the parameters? What is the return value?
    Initialise any variables, e.g. set total to 0
    Start coding your bullet points
        Can you code the main calculation?
    Check your loops
    Check the code produces the right answer (hand trace)

Here are the diagnostic questions again:

Write a function to convert a 2 digit hexadecimal number into denary. The hexadecimal number is passed as a parameter to the function. The subroutine hex_digit(x) converts a single hex digit from 0 to F into the equivalent denary number and you may use this function in your solution if you wish

Solution:

```
function hex_to_den(hex)
  digit0 = hex[0]
  den0 = hex_digit(digit0)
  digit1 = hex[1]
  den1 = hex_digit(digit1)
  denary = 16*den0 + den1
  return denary
```

You'll get a mark for

- the function definition – you can always give the name of your function and any define any parameters
- the correct return value
- using the subroutine provided – check what is given to you in the question. Remember to only write the function requested, for example don't start worrying about uer input if that is handled by a subroutine.
- the correct calculation
- using the indexes correctly

Here are the test marks for several students on different topics.
Write an algorithm to find the range of the marks

Alex	80	85	83	79	92
Bob	87	88	90	84	87
Charlie	95	95	100	95	95
Danni	92	93	92	96	98

Step 1
This is a 2D array, so probably two for loops

```
for i = 0 to 3
   for j = 1 to 5
   next j
next i
```

Step 2
We need to identify the key calculation and what data is needed
In this case we need the range, so we need the largest and smallest values in the array
These are standard patterns from earlier

```
max = scores[0,1] #set to first value in array to give something to compare to
min = scores[0,1]
for i = 0 to 3
   for j = 1 to 5
   next j
next i
```

```
max = scores[0,1] #set to first value in array to give something to compare to
min = scores[0,1]
for i = 0 to 3
   for j = 1 to 5
      if scores[i,j] > max then
         max = scores[i,j]
      end if
      if scores[i,j] < min then #this could be an elseif
         min = scores[i,j]
      end if
   next j
next i
```

Step 3
complete the calculation and return the answer

```
max = scores[0,1] #set to first value in array to give something to compare to
min = scores[0,1]
for i = 0 to 3
   for j = 1 to 5
      if scores[i,j] > max then
         max = scores[i,j]
      end if
      if scores[i,j] < min then #this could be an elseif
         min = scores[i,j]
      end if
   next j
next i
range = max – min #could return max-min directly
return range
```

Notice how we built this up by combining known patterns.
It doesn't really matter what is in the array. We just loop through it and pick out the required values for the calculation.

Explain the benefits of defensive programming

2 marks for valid points
2 marks for valid examples or explanations of points

e.g.

- Input validation prevents the program from crashing
- By ensuring that input are of the correct data types
- Such as integers for calculations

- Input sanitisation avoids security issues
- Such as SQL injection
- By removing command characters from input boxes

Explain two features of an IDE that help developers write robust code

1 mark for named feature
2 marks for valid explanation

Example
One feature of an IDE that aids development of robust code is a run-time environment that allows the developer to test code without having to compile it and install it on the target device. For example, an android developer could use a run-time environment to test that a program works on many different phones without owning them

Another feature of an IDE is code completion and syntax highlighting, which may help the developer to use a good coding style by automatically indenting code correctly and by enforcing the use of sensible variable names.

In this case no context was given, so you can give your own examples
However, you may need to relate you points to a scenario

Practice

1. Write an algorithm to find the total price of this order

The order is stored in an array called order like this:

85	102	76	130	26

Items over £100 get a 10% discount
VAT must be added at the end at 20%

2. Write an algorithm to
   - Ask the user to input a sequence of test scores
   - Calculate the average of the scores
   - The program should ask for inputs until the user inputs -1
     - this value is not included in the average

3. Using the scores array from before

   a) Write an algorithm to find the student with the lowest range in their scores

   b) Write an algorithm to store any students with an average score below 90 in an array

4. Ask the user for a password and check that it contains

- at least 8 characters
- at least one number
- at least one uppercase and one lowercase character

Output "valid" if it meets all three conditions or a suitable error message if not

Note that ord(c) returns the ASCII code for a character
(You can check in the text book the ASCII ranges for uppercase, lowercase and numbers)

5. Find the name of the first item that costs more than £200
The names and prices are stored in two 1D arrays like this

names

T-shirt	Trousers	Boots	Jacket	Hat	Rucksack	Tent

prices

10.0	36.99	99.99	129.99	12	104.99	230.0

Notice how you can come up with lots of variants easily for more practice, for example

- Change the calculation
- Add layers of complexity, such as discounts

6. This algorithm is supposed to find the median of list of numbers, stored in a 1D array called "numbers"
Correct the code

```
n = numbers.length #alternative way to get the length of a list or array
mid = numbers / 2
median = numbers[mid]
OUTPUT median
```

7. Here is an algorithm to count the number of prices greater than or equal to £100 in a list called *prices*

```
x = 0
for i = 1 to len(prices) – 1
if list[i] > 100 then
x = x + 1
end if
next i
print x
```

Fix an error in the algorithm
Explain how the developer could have improved the code to make it easier to maintain

Sample answers

1.

```
total = 0
for i = 0 to len(order)-1
   if order[i] > 100 then
      total = total + order[i]*0.9
   else
      total =  total + order[i]
  end if
total = total*1.2
print total
```

2.

```
score = 0
total = 0
count = 0
while score <> -1
   OUTPUT "Please enter a score"
   INPUT score
   if score <> -1 then
      total = total + score
      count = count + 1
   end if
end while
OUTPUT total/count
```

3. See earlier example – can you adapt it?

4.

```
valid = False
while not valid
   len = False
   lower = False
   upper  = False
   num = False
   OUPUT "Please choose a password"
   INPUT password
   for i = 0 to password.length – 1
      code = ord(password[i])
      if 48 <= code <= 57 then
         num = True
      else if 65 <= code <= 90 then
         upper  = True
      else if 97 <= code <= 122 then
        lower = True
      end if
   if password.length  >= 8 and upper and lower and num then
      OUTPUT "Valid"
      valid = True
   end if
end while
```

5. See earlier array patterns

6.

```
n = numbers.length #alternative way to get the length of a list or array
numbers.sort #sort the list before finding the median
if n MOD 2 == 1 then #i.e. if n is an odd number
  mid = n-1 / 2 #-1 as the indexes start at 0
  median = numbers[mid]
else
   mid = n/2
   median = (numbers[mid] + numbers[mid-1]) / 2 #average of the two middle numbers
end if
OUTPUT median
```

7.

```
count = 0 #use meaningful variable names
for i = 0 to len(prices) – 1 #index from 0
   if prices[i] >= 100 then #check name and >=
      count = count + 1    #use indentation to improve readability
   end if
next i
print count
```

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If you want extra practice coding beyond GCSE try these:

Think Python: a very good book (and free!) explaining thinking strategies for problem solving and how these link to code. Chapters 1-14 are sufficient for GCSE.
http://openbookproject.net/thinkcs/python/english3e/

BIO: the British Informatics Olympiad. Lots of hard coding problems. Like the maths challenge... only for programming!
http://www.olympiad.org.uk/

Final thoughts

Getting a top grade is about practicing the knowledge, understanding and skills required to get full marks in such a way as to produce your best on the day. This includes having an A* mind-set.

- Be confident in your ability to answer questions.
- Start with a simple point... and then build on it
- Practice all the points in the specification to 3 mark depth
- Use connectives to improve your writing style
- Use technical language in context
- Read the question and refer to the context
- Check your answers carefully
- Read around the subject

You chose to study this and you are working at the top grades – enjoy it and show off!

Good luck!

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OUT OF LESSON WORK

TERM 1

COMPUTER SCIENCE

YEAR 11

PONTEFRACT
ACADEMIES TRUST

Computer Science

Term 1

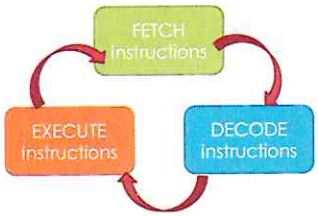
Name: _____

The Function of the CPU

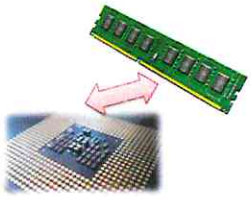
What is the Purpose of the CPU?

The CPU is often known as the 'brain of the computer'. Its job is to process data. And by processing we mean things like searching, sorting, calculating and decision making. Whenever you are on working on your computer, it is the CPU which is at the heart of everything.

The CPU follows three steps in order to process data. It is known as the Fetch - Decode - Execute cycle (aka Fetch-Execute Cycle).

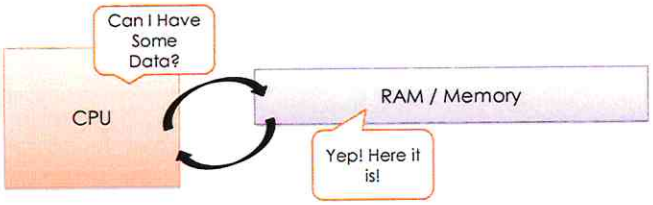


To begin with, whenever you open and work with a program, its data and instructions are loaded onto the RAM. As the RAM is accessed directly by the CPU, the CPU can get to work!



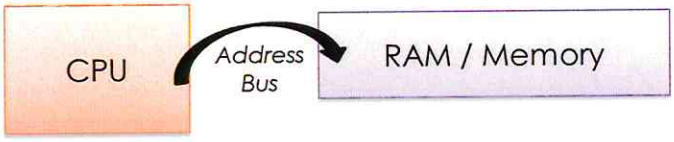
The Fetch Stage

In this step the CPU fetches some data and instructions from main memory (RAM) and then stores them in its own temporary memory called 'registers'.

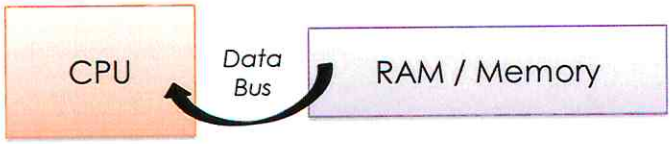


For this to happen, the CPU uses a piece of hardware path called the 'address bus'.

The address of the next item that the CPU wants is put onto the 'address bus'.



Data from this area then travels from the RAM to the CPU on another piece of hardware called the 'Data Bus'.



The Decode Stage

The decode step is where the CPU understands / works out what the instruction it has just fetched actually means. The CPU 'decodes' the instruction and gets things ready for the next step.

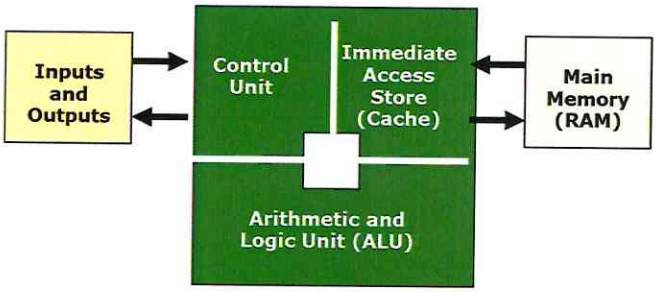
The Execute Stage

The Execute stage is where data processing happens. Instructions are carried out on the data. Once a cycle has been completed, another begins.

What makes up a CPU?

Now that we know the basic actions performed by the CPU it's time to look at the areas of the CPU responsible:

- Control Unit
- Immediate Access Store (IAS) or "Cache"
- Arithmetic and Logic Unit (ALU)



The Control Unit

There are three main jobs of the Control Unit:

- It manages and monitors hardware on the computer to ensure the correct data goes to the correct hardware.
- It manages the input and output signals ensuring these are dealt with correctly.
- It uses clock signals to synchronise the running of the Fetch-Decode-Execute cycle.

Immediate Access Store (Cache)

This part stores the data which is to be immediately processed. The CPU takes a chunk of data / instructions from the RAM and keeps it close so that it always has a constant supply of data to process. If data and instructions were moved from the RAM one instruction at a time, the CPU would work far slower because the CPU cycles much faster than the RAM can deliver data. So instead, chunks are moved from the RAM and stored on the cache so the CPU doesn't spend wasted time waiting for a delivery of data. Efficiently coded programs will also ensure that regularly used instructions are stored in the cache so that they can be accessed regularly, at speed.

Arithmetic and Logic Unit (ALU)

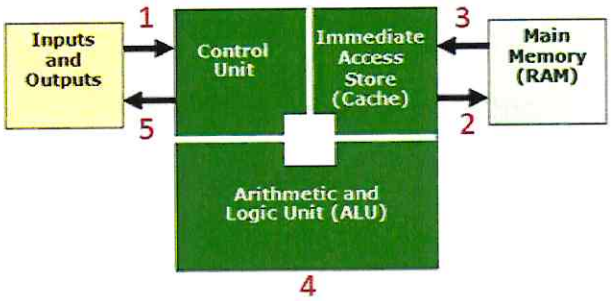
This is where the CPU actually carries out the maths and logic on the data (processes it).

It has two parts:

- Arithmetic part, which performs calculations on the data, e.g. 3 + 2 = 5
- Logic part, which deals with logical operations such as is True / False / Equal to / Greater than etc.

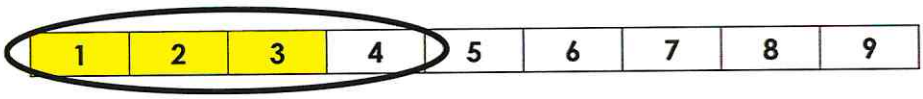
Summary of the journey of data / instructions around the CPU

1. An input device (e.g. keyboard) sends data to the CPU. The Control Unit receives this data.
2. The Control Unit sends this data into main memory to be used later.
3. When the time is right, the data will be transferred from main memory into cache (IAS)
4. The data will then be sent to the ALU for processing
5. The control unit will send the processed data back (for example to an output device such as a screen or monitor).



Questions *(The question zone you choose must either match your target grade or be higher!)*

Question Zone 1-3

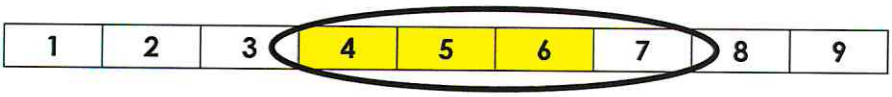


1. State the names of the 3 main components that make up the CPU. [3]

2. Define the words 'decode' and 'execute', in relation to the function of the CPU. [2]

3. Describe what happens during the F-D-E cycle. [3]

Question Zone 4-6

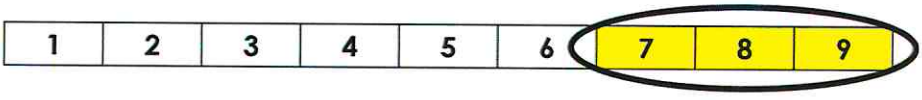


1. Describe what happens during the F-D-E cycle. [3]

2. Describe the roles of both the address and data bus. [2]

3. Explain the job of the CPU's control unit. [6]

Questions Zone 7-9



1. Explain the job of the CPU's control unit. [6]

2. Explain, using a diagram, the journey of an instruction from input device to output device. [5]

3. Discuss differences between the roles of both the RAM and the cache in how data is delivered to the CPU, during the fetch-decode-execute cycle. [4]

The Von Neumann Architecture

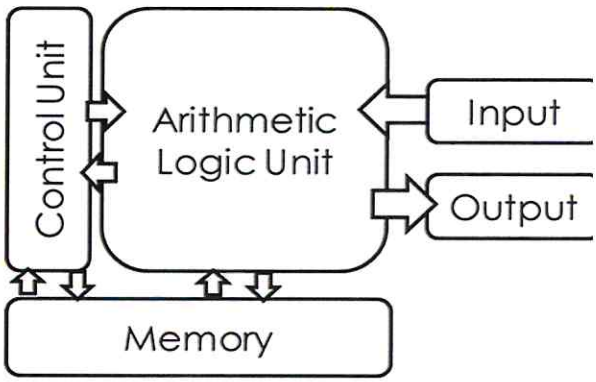
Von Neumann

Before 1945, computers were essentially preprogramed machines. This meant that a computer would typically be set up, with wires and switches to perform a specific task. In this way, a computer program was considered to be part of the machine. The only thing it would be given is data to be processed.

In 1945, a mathematician from the USA called John Von Neumann, had an idea. He wondered if it would be possible to create a computer where the program (and its data) could be stored together, independent of 'the machine'. This meant that the same computer could work, no matter what program it was given. No more hours setting up machines, instead, the time would be spent on creating the program instructions!

Von Neumann Architecture

In the Von Neumann architecture, the data and instructions could be held together in memory and then fetched, decoded and executed one at a time. This meant that simple programs could be written containing both instructions and data and be executed by a computer without having to rewire the circuitry of the machine. It wasn't long before computer scientists invented a simple coding language which would make programming software, accessible to the masses.



Assembly Language and the Von Neumann Architecture

All 'Von Neumann' CPUs have an instruction set. This means that it has a list of instructions that it understands and knows what to do with. Surprisingly, a CPU's instruction set only consists of a few simple instructions.

Here is an example instruction set:

Instruction	Purpose
ADD	Add numbers together
SUB	Subtract numbers from each other
STA	Store value in the accumulator
LDA	Load value from the accumulator
BRA	Branch to a different part of the program (often used to repeat code)
OUT	Output a value (after processing)

A CPU is able to perform each of these instructions and it does so using some very important parts of the Von Neumann Architecture. These parts are called registers, which are simply tiny memory locations (memory stores). The important ones have special

names. The following registers are used during each Fetch-Decode-Execute cycle in order to carry out each instruction:

The Accumulator (A)

The Program Counter (C)

The Memory Address Register (MAR)

The Instruction Register (IR)

The Memory Data Register (MDR)

Let's take a look at how these registers carry out simple instructions in a typical F-D-E cycle.

An Example of the Von Neumann Architecture at work...

Below is an example of some instructions and data from a program which has just been loaded into the CPU ready for processing.

Address	**00**	**01**	**02**	**03**	**04**
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	**05**	**06**	**07**	**08**	**09**
Instruction / Data	2				

The Program Counter (C)	
The Memory Address Register (MAR)	
The Memory Data Register (MDR)	
The Instruction Register (IR)	
The Accumulator (A)	

FETCH STAGE

In the first part of the cycle, the instructions and data are fetched from the CPU memory and loaded into the specialised registers:

The Program Counter (C)	0
The Memory Address Register (MAR)	
The Memory Data Register (MDR)	
The Instruction Register (IR)	
The Accumulator (A)	

Address	**00**	**01**	**02**	**03**	**04**
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	**05**	**06**	**07**	**08**	**09**
Instruction / Data	2				

The Program Counter (C)	0
The Memory Address Register (MAR)	0
The Memory Data Register (MDR)	
The Instruction Register (IR)	
The Accumulator (A)	

Address	**00**	**01**	**02**	**03**	**04**
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	**05**	**06**	**07**	**08**	**09**
Instruction / Data	2				

The Program Counter (C)	0
The Memory Address Register (MAR)	0
The Memory Data Register (MDR)	
The Instruction Register (IR)	
The Accumulator (A)	

Address	**00**	**01**	**02**	**03**	**04**
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	**05**	**06**	**07**	**08**	**09**
Instruction / Data	2				

The Program Counter (C)	0
The Memory Address Register (MAR)	0
The Memory Data Register (MDR)	LDA 4
The Instruction Register (IR)	LDA 4
The Accumulator (A)	

Address	**00**	**01**	**02**	**03**	**04**
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	**05**	**06**	**07**	**08**	**09**
Instruction / Data	2				

DECODE STAGE

Now that the CPU has fetched the first instruction, it needs to decode it.

The Program Counter (C)	0
The Memory Address Register (MAR)	0
The Memory Data Register (MDR)	LDA 4
The Instruction Register (IR)	LDA 4
The Accumulator (A)	

The Instruction Set

Instruction	Purpose
ADD	Add numbers together
SUB	Subtract numbers from each other
STA	Store a value
LDA	Load a value
BRA	Branch to a different part of the program (often used to repeat code)
OUT	Output a value (after processing)

EXECUTE STAGE

Now that the CPU has made sense of the instruction, it now needs to execute the instruction.

The Program Counter (C)	0
The Memory Address Register (MAR)	0
The Memory Data Register (MDR)	LDA 4
The Instruction Register (IR)	LDA 4
The Accumulator (A)	5

Address	00	01	02	03	04
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	05	06	07	08	09
Instruction / Data	2				

The Program Counter (C)	1
The Memory Address Register (MAR)	0
The Memory Data Register (MDR)	LDA 4
The Instruction Register (IR)	LDA 4
The Accumulator (A)	5

Address	00	01	02	03	04
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	05	06	07	08	09
Instruction / Data	2				

FETCH STAGE

Now the second cycle begins and the next instruction is fetched from memory.

The Program Counter (C)	1
The Memory Address Register (MAR)	
The Memory Data Register (MDR)	
The Instruction Register (IR)	
The Accumulator (A)	5

Address	00	01	02	03	04
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	05	06	07	08	09
Instruction / Data	2				

The Program Counter (C)	1
The Memory Address Register (MAR)	1
The Memory Data Register (MDR)	
The Instruction Register (IR)	
The Accumulator (A)	5

Address	00	01	02	03	04
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	05	06	07	08	09
Instruction / Data	2				

The Program Counter (C)	1
The Memory Address Register (MAR)	1
The Memory Data Register (MDR)	
The Instruction Register (IR)	
The Accumulator (A)	5

Address	00	01	02	03	04
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	05	06	07	08	09
Instruction / Data	2				

The Program Counter (C)	1
The Memory Address Register (MAR)	1
The Memory Data Register (MDR)	SUB 5
The Instruction Register (IR)	SUB 5
The Accumulator (A)	5

Address	00	01	02	03	04
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	05	06	07	08	09
Instruction / Data	2				

DECODE STAGE

Now that the CPU has fetched the next instruction, it needs to decode it.

The Program Counter (C)	1
The Memory Address Register (MAR)	1
The Memory Data Register (MDR)	SUB 5
The Instruction Register (IR)	SUB 5
The Accumulator (A)	5

The Instruction Set

Instruction	Purpose
ADD	Add numbers together
SUB	Subtract numbers from each other
STA	Store a value
LDA	Load a value
BRA	Branch to a different part of the program (often used to repeat code)
OUT	Output a value (after processing)

EXECUTE STAGE

Now that the CPU has made sense of the instruction, it now needs to execute the instruction.

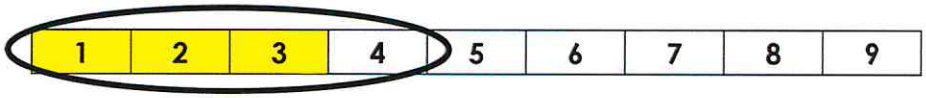
The Program Counter (C)	1
The Memory Address Register (MAR)	1
The Memory Data Register (MDR)	SUB 5
The Instruction Register (IR)	SUB 5
The Accumulator (A)	5

Address	**00**	**01**	**02**	**03**	**04**
Instruction / Data	LDA 4	SUB 5	STA 6		5
Address	**05**	**06**	**07**	**08**	**09**
Instruction / Data	2				

The Program Counter (C)	1
The Memory Address Register (MAR)	1
The Memory Data Register (MDR)	SUB 5
The Instruction Register (IR)	SUB 5
The Accumulator (A)	3

Questions *(The question zone you choose must either match your target grade or be higher!)*

Question Zone 1-3

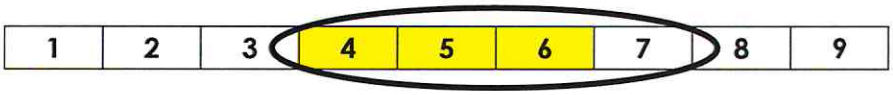


1. State the assembly language instruction used to stores data in the accumulator. [1]

2. Define the term 'instruction set'. [2]

3. Describe the role of each of the 5 main CPU registers. [5]

Question Zone 4-6

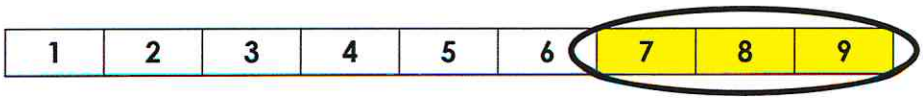


1. Describe the role of each of the 5 main CPU registers. [5]

2. Using the example program in the table provided, describe the purpose of the program making reference to the instructions and data given. [4]

Address	00	01	02	03	04
Instruction / Data	LDA 4	ADD 5	STA 6		5
Address	05	06	07	08	09
Instruction / Data	9				

3. Explain the difference between the MAR and the MDR. [2]



Question Zone 7-9

1. Explain the difference between the MAR and the MDR. [2]
2. Using the example program in the table above, explain the process involved in fetching, decoding and executing the first instruction. Make sure that you reference the major registers in your answer. [5]
3. Discuss the importance of Von Neumann in the development of computer technology. [5]

Characteristics of the CPU

Introduction

There are a number of common characteristics of a CPU. For your exam, you need to understand what these characteristics are and how they affect the performance of a computer. The next few pages will introduce these characteristics and explain their importance.

Clock Speed

The speed of the Fetch-Decode-Execute cycle is determined by the CPU's clock chip. This chip uses a vibrating crystal that maintains a constant rate. The speed of the clock is measured in hertz (Hz) which is the amount of cycles per second. A clock speed of 500Hz means 500 cycles per second. Current computers have CPU clock speeds of 3GHz which means 3 Billion cycles per second.

Overclocking

It is possible to increase the clock speed for a CPU. This is known as overclocking. In theory, if the clock is faster than the CPU can perform more calculations and perform faster.

The problem is that CPUs get hotter the more work they do – so overclocking is dangerous without the appropriate heat management.

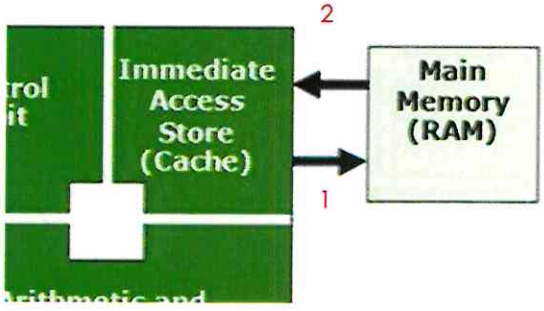
The Cache

As we have just seen CPUs can work very quickly indeed but unfortunately CPUs can only work when supplied with data. The RAM (that supplies the data) cannot work at the same speed. To overcome this the CPU's cache memory will not just copy the instruction needed at that time, instead it will also copy the continuing instructions. Cache memory has read speeds similar to the CPU and is therefore much faster than RAM.

So, to improve efficiency the CPU's 'Control Unit' will look first in the cache for the next instruction to see if it has already been copied which reduces the time taken to access data. If the cache is larger, it is more likely that the next required instruction has already been transferred from the RAM to the CPU thus improving process time.

1. If the required data is not in the cache, the control unit will request it from RAM

2. Data/Instructions (and future instructions) copied to cache for quicker access



CPU Cores

CPUs of today are pretty much at the limit of today's technology. So if CPUs can't go faster, the solution its to add 2 CPU chips, or 4, or 8, etc). These chips are called 'cores'. Because the various cores can each carry out their own Fetch – Decode – Execute cycle it means that instructions can be processed at the same time. Allowing a CPU to process MORE data during the same time period.

There are two ways in which a CPU with more than one core can process more instructions in the same time period:

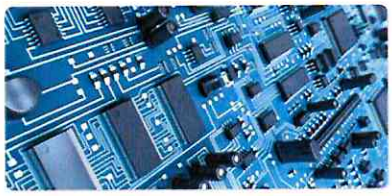
- They can carry out Parallel Processing which is when the same program can have two instructions processed at the same time.
- More cores also enables Multi-Tasking where each core can each process two different programs' instructions at the same time.

Either way, more cores means more instructions being processed at once. However, it doesn't necessarily mean CPUs work faster as some programs do not allow more than one instruction to be processed at once, so be careful when answering exam questions on this!

Embedded Systems

For your exam, you will also need to understand what an embedded system is. When we think of a computer, you usually think of a PC and as many of you know, a PC is made up of various components including a motherboard, CPU, RAM, input devices etc. But of course a computer is any programmable machine…or any electronic device which takes in data, processes it and then outputs the result.

So when you consider devices like cameras and watches, as these are programmable machines, they can also be called computers. The main difference is that these computers run specific tasks – they are not general purpose. Because of this, they do not need to have separate components as these devices won't need updating when new software / hardware is released. These systems instead have all of their components arranged together on a single circuit board.

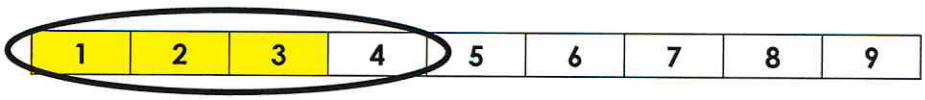


Source:
http://neuronelab.unisa.it

As a result they are known as embedded systems as all of their hardware is embedded together as one.

Questions *(The question zone you choose must either match your target grade or be higher!)*

Question Zone 1-3



1. State what is meant by the CPU's clock speed and what is meant by the term overclocking. [3]

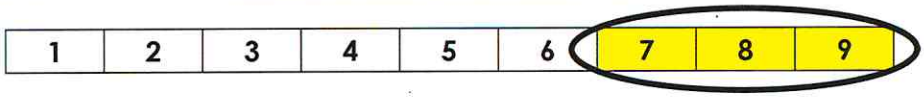
2. Describe what is meant by the term 'cores', when it comes to CPU architecture. [2]

Question Zone 4-6

1. Describe the role of cache in a computer system. [3]

2. Explain the effects that a higher clock speed will have on the performance of a CPU. [4]

3. Explain the term 'parallel processing' in relation to CPU cores. [4]



Question Zone 7-9

1. Explain the need for cache memory and the reason why larger cache will improve performance. [5]

2. Discuss the accuracy of the statement "A CPU with more cores will always outperform those with fewer". [5]

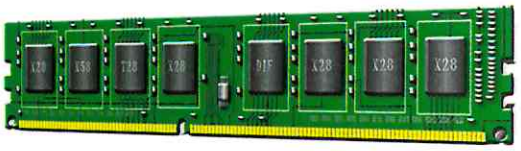
Memory

Introduction

Memory is where binary data (0s and 1s) is stored. There are several devices in a modern computer which store data. They store this data in different ways and for different purposes. We shall now take a look at each type of memory device:

- RAM
- ROM
- Virtual Memory

RAM Random Access Memory – AKA Main Memory

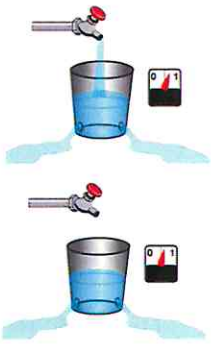


RAM is needed to store programs that are currently being used. They help to enable 'multi-tasking', which means having several programs open and using them all at the same time. It does this by copying the data needed by programs at that time so that it can be passed to the CPU when it needs to process that data. It also stores all the instructions/modules from the open programs that the CPU will require for processing.

RAM stores data as small charges of electricity in tiny transistors etched into a circuit in the device. The charge needs to be refreshed every few milliseconds otherwise the charge leaks away. RAM is therefore volatile memory – it loses data when there is no power.

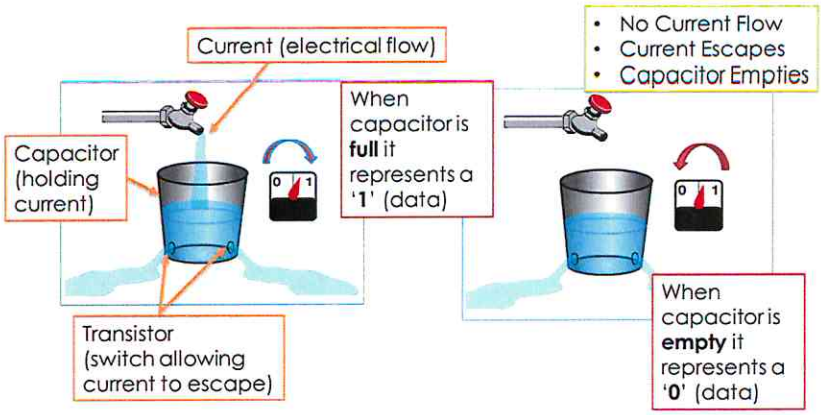
When programs are opened by the user, they are loaded from the hard disk onto the RAM. This is so that the CPU can access the data and instructions at an acceptable rate. If the CPU reads the program instructions and data from a hard disk, the data access would be extremely slow – this is why RAM is so important.

How does RAM store data?



Ram holds data using capacitors and transistors. A capacitor can be thought of as a sink or bucket holding water. When it is full it's holding a 'bit' of data (1), when it is empty it represents a zero (0). But obviously in RAM it holds an electrical current (not water). The transistor acts as a switch that lets the computer read the what is in the capacitor (bucket) or fill it up or empty it (change its state).

How Capacitors and Transistors Work – a brief overview!



Types of RAM

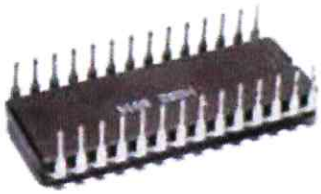
Dynamic RAM

1 transistor and 1 capacitor for each bit – hold a small charge for a few milliseconds then needs to be refreshed. Because it needs refreshing, there is a limit as to how fast data can be read on this type of RAM. Power is always needed.

Static RAM

4-5 transistors wired together for each bit of data, but it does not lose its charge No need to refresh every few milliseconds – therefore much faster as they don't need refreshing. Does still need constant electricity supply. Faster but more expensive!

ROM - Read Only Memory



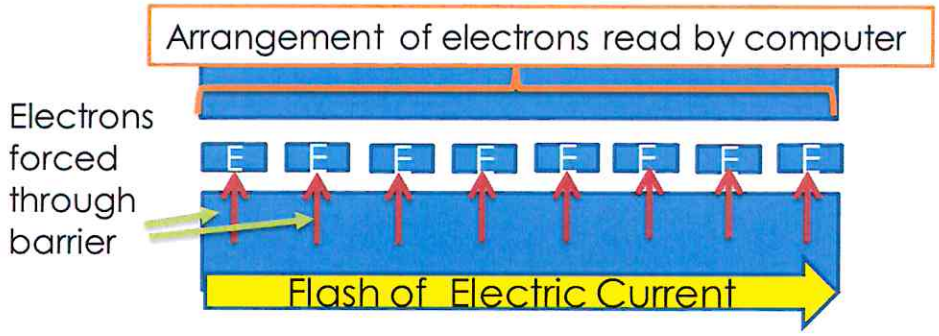
When you switch off your computer the data that the CPU can access (i.e. the RAM) loses its data. This is a problem because, when you restart your computer, data must be in the RAM for the computer to work. This is where ROM comes in.

ROM is a special memory chip that can store data even without power – it is non-volatile. It is used by a computer to store the boot sequence instructions – everything the computer needs to boot (start-up) and load the operating system. When you switch on your computer, data in the ROM is accessed by the CPU in order to start the computer and load the operating system successfully. The data on ROM cannot easily be over written by the user.

Like the RAM it is classed as Primary Storage (memory that is directly accessed by the CPU) & has fast data access rates. Modern ROM chips are now made of flash memory. This is a suitable type of storage technology because it doesn't need constant power supply to hold data.

How Flash Memory Works

Flash memory works by sending a large electric current to force electrons through a barrier and trapping them in position.



The flash of the electric current used to achieve this gives us the name for this type of memory. The different arrangement of electrons gives us data.

Virtual Memory

If you are browsing the internet and listening to music, the RAM should cope fine. If you then decide to play a game with good graphics then this may overload the RAM as too many programs (and their data) will need to be loaded onto the RAM. So that the system doesn't grind to a halt and freeze up, the computer will relocate programs that have not been recently used to secondary storage (e.g.: the hard disk). This process will take time as hard-disk data speeds are much slower – but when it is done the system should be nice and fast again. Often the operating system will use the hard disk as virtual memory. A lot of programs need to be loaded as part of the operating system but many can sit on the hard-disk as they are used infrequently.

How the amount of RAM affects performance

So as we've just seen, RAM is needed to supply to the CPU with data and instructions from programs currently in use and when it gets full, the system runs slower as a result of the need to use virtual memory. Therefore the following is true:

- Smaller amounts of RAM – limited multi-tasking and greater need to use slower virtual memory
- Larger amounts of RAM – greater storage of programs / data leading to faster performance and effective multi-tasking.

Cache Memory

We have already seen cache memory when studying the workings of the CPU. We will now look at it in a little more detail.

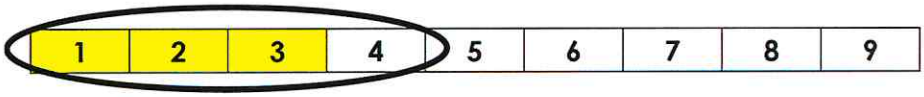
As we have seen before, RAM will hold a copy of data and instructions (program) that are currently being used by the user. And unfortunately, as the CPU processes data faster than the RAM can supply it with data, system performance can suffer. This is where cache comes in…

Cache is simply a few Mb of memory that sits inside the CPU. Being located in the CPU means that data access speed is equal to the CPU's speed. CPU performance is therefore maintained. Well written programs will make sure that 'sets' of regularly used instructions are copied to the cache so that the program can run more efficiently and

much faster. Poorly written programs will tend to need to fetch the instructions they require from the RAM one at a time and so, as access to the RAM is slow, the program performs less efficiently.

Questions *(The question zone you choose must either match your target grade or be higher!)*

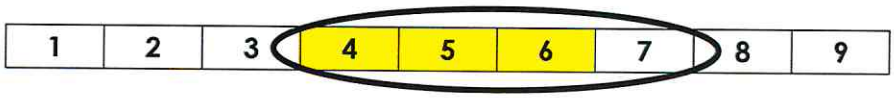
Question Zone 1-3



1. State the difference between 'volatile' and 'non-volatile' memory. [2]

2. Describe the purpose of RAM and ROM. [2]

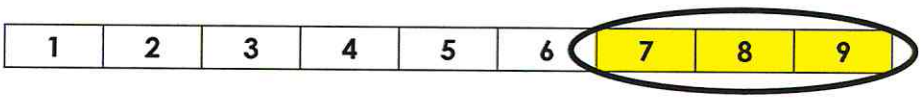
Question Zone 4-6



1. What is virtual memory and why is it important. [3]

2. Explain the effects of the amount of RAM a computer has on its performance. [4]

Question Zone 7-9



1. Explain, using a diagram, how flash memory technology works. [4]

2. Explain, using a diagram, how RAM memory technology works. [5]

3. Discuss the relative importance of ROM, RAM and Virtual Memory in a computer system. [5]

Storage

Introduction

In everyday computer use, we need a way to write data, rewrite data, store data when the computer is switched off and retrieve data the next time we switch our computer back on. We have already looked at system/primary memory:

- RAM allows us to write data and store it…but the data is lost when it is switched off (volatile).
- ROM allows us to store data when it has no power (non-volatile)…but we cannot write to it.

We therefore need another device/medium by which we can re-write data when we want AND store the data when the computer has no power. This is where SECONDARY STORAGE comes in!

Storage Technologies:

Magnetic storage

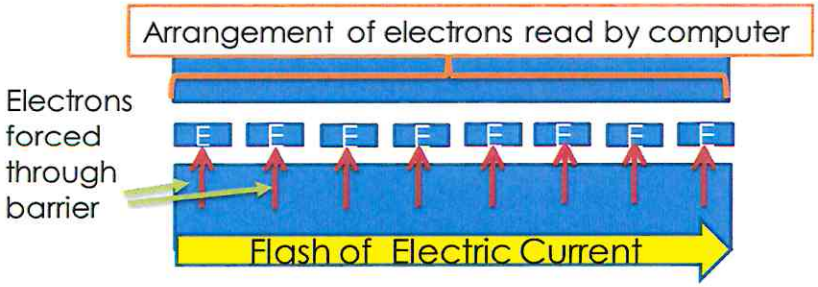
Magnetic storage uses different patterns of magnetisation in a magnetisable material to store data (tape/hard disk). Magnetised points on a pattern represents '1' and demagnetised points represent '0'

Optical storage

Optical storage consists of 'marks' arranged in patterns. When writing to optical media the laser burns 'pits' into the shiny surface (land). When reading optical media a light (laser) is shined on its surface. When it hits land the beam reflects (0) but when it hits the pits, it doesn't (1).

Solid State Storage (Flash)

They work by sending a large electric current to force electrons through a barrier and trapping them in position. The flash of the electric current used to achieve this gives us the name for this type of memory. The different arrangement of electrons gives us data.



Magnetic Storage Performance

Hard Disk
(Hard Drive)

Use	Desktop computers to store large files, programs and operating systems
Capacity	750GB – 3TB (3000GB) (Large)
Speed	High read/write speeds
Portability	Heavy / poor portability (even external are clunky!)
Durability	Dropping this device could cause damage, especially to the 'read head'
Reliability	Can be used again and again but does have a limited life (a good few years)
Cost	Low cost (quite cheap)

Magnetic
Tape

Use	Backing up vast amount of data
Capacity	1 – 5TB (Very Large)
Speed	High write speeds BUT Slow read speeds
Portability	Fairly small and light (but reading device is not because if the data you need is at the end of the tape you have to read/play the tape from the start – which takes time (known as serial access))
Durability	Fairly durable.
Reliability	Can be used again and again.
Cost	Cheap

Optical Storage

CD-ROM

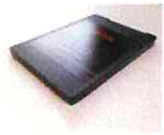
Use	Storage of small media files and documents
Capacity	650MB (Small)
Speed	Moderate read/write speeds
Portability	Very portable and light
Durability	Fair durability, can survive the odd knock but scratches can damage the data.
Reliability	CD-Rs are write once but can be read over and over. (CD-RW can be reused)
Cost	Very cheap

BLU-RAY

DVD-ROM

Use	Storage of larger media files and documents
Capacity	4.37GB (DVD) 25GB (Standard Blu-Ray) (Small)
Speed	Moderate read/write speeds
Portability	Very portable and light
Durability	Fair durability, can survive the odd knock but scratches can damage the data.
Reliability	DVD-Rs are write once but can be read over and over.
Cost	Very cheap

Solid State / Flash Storage



Solid State Drive

Use	Desktop computers, laptops and tablets to store large files, programs and operating systems
Capacity	64GB – 480GB (Moderate)
Speed	Super Fast (Read/Write)
Portability	Very portable (small and lightweight)
Durability	No moving parts so can survive knocks and scrapes

Flash
SD Card

Use	Phones, Cameras (portable devices) – great choice as no moving parts so mobile devices can function whilst on the move
Capacity	16GB – 64GB
Speed	Super Fast (Read/Write)
Portability	Extremely portable (small and lightweight)
Durability	No moving parts so can survive knocks and scrapes
Reliability	Can be re-used many times (up to 100,000 times)
Cost	Expensive (per Gb)

Flash Memory
Stick

Use	Backing up or transferring documents, small media files from computer to computer
Capacity	1GB – 64GB
Speed	Super Fast (Read/Write)
Portability	Extremely portable (small and lightweight)
Durability	No moving parts so can survive knocks and scrapes
Reliability	Can be re-used many times (up to 100,000 times)
Cost	Expensive (per Gb)

Network Attached Storage (NAS)

NAS Drive

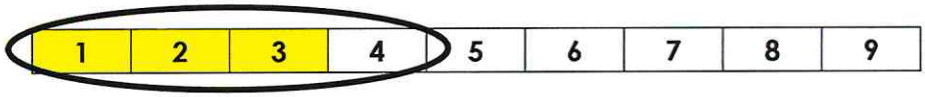
Use	A stand alone external hard drive at the centre of a network. Plugs into the network to allow users of different computers to write or read files. Usually documents and media files.
Capacity	750GB – 3TB (3000GB) (Large)
Speed	Hard disk has high read/write speeds The network speed (transfer of data from computer to NAS) can cause slow data access speeds
Portability	Heavy / poor portability.
Durability	Dropping this device could cause damage, especially to the 'read head'
Reliability	Can be used again and again but does have a limited life (a good few years)
Cost	If Hard Disk is used then storage is cheap If SS Disk is used then storage is expensive In addition to the storage, the NAS enclosure can be very expensive depending on its features.

Cloud Storage (online storage)

Use	Used to store documents and media files online. This means that you can go to another computer and access your files (providing you have internet access).
Capacity	Unlimited (providing you can pay for it).
Speed	Depends on network / bandwidth speeds Poor bandwidth can cause uploading and downloading of large files to take a long time
Portability	It is virtual so you don't have anything physical to move around.
Durability **Reliability**	Providing you keep up payments and the company looks after their storage devices – very durable and reliable. This is often because they back up storage devices in many places. There can be issues with the law as a company's data may be stored in a country which doesn't follow the same data protection laws. The hosting company could also me attached by hackers who could steal your data.
Cost	Can be expensive depending on the service – but often it is free for a few Gbs.

Questions *(The question zone you choose must either match your target grade or be higher!)*

Question Zone 1-3

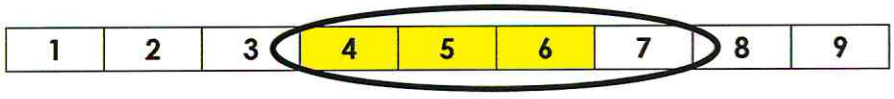


1. State the 3 different storage technologies. [3]

2. Describe how optical storage devices store data. [3]

3. What is the need for secondary storage if a computer system already has primary memory (RAM/ROM)? [3]

Question Zone 4-6

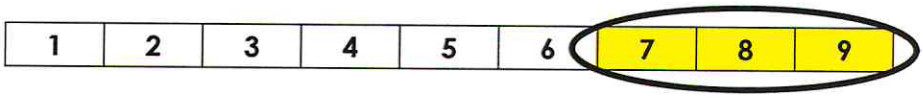


1. What is the need for secondary storage if a computer system already has primary memory (RAM/ROM)? [3]

2. Which secondary storage technology would be most appropriate for a mobile phone? Explain your answer. [4]

3. Magnetic tape storage can store large capacities but there is a major drawback when it comes to reading data from this technology. Explain the drawback. [3]

Question Zone 7-9



1. Magnetic tape storage can store large capacities but there is a major drawback when it comes to reading data from this technology. Explain the drawback. [3]

2. Explain which storage device is best suited to storing an operating system. [5]

3. Discuss the relative advantages and disadvantages of the 3 main storage technologies (optical, magnetic (hard disks), solid state). [5]